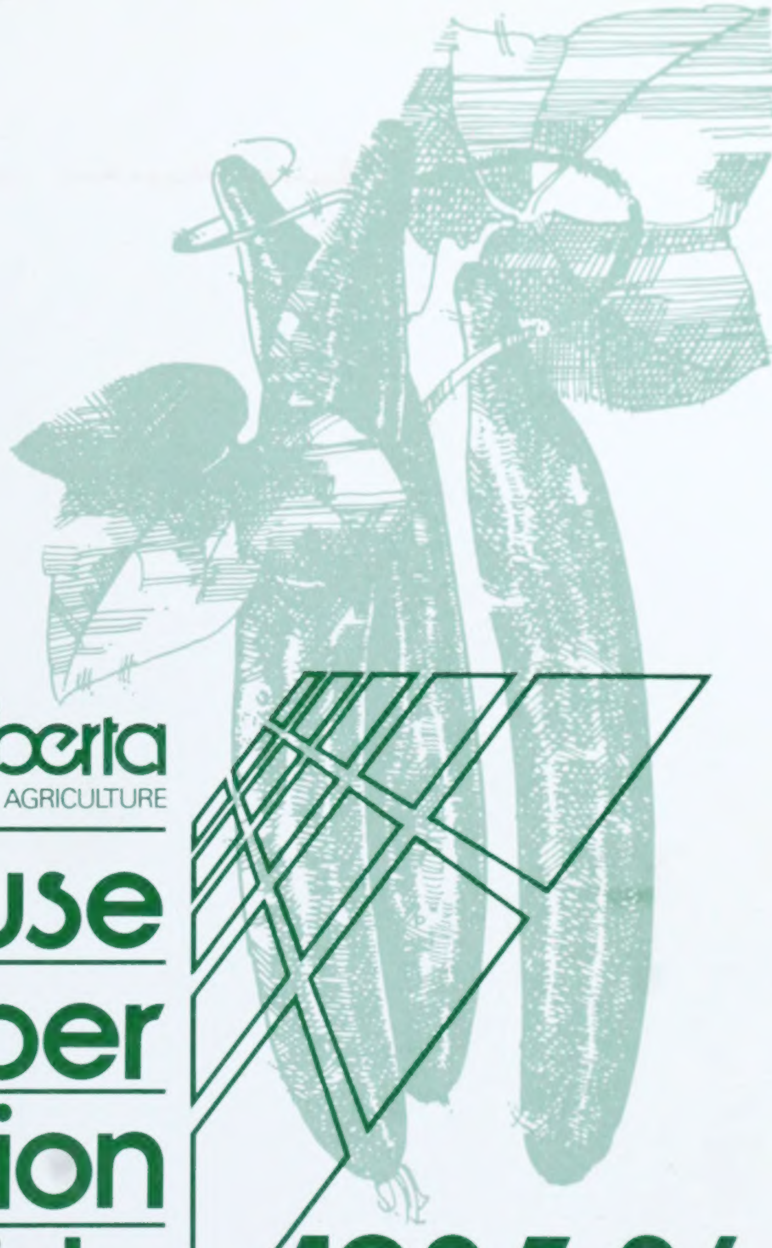

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GREENHOUSE CUCUMBER PRODUCTION GUIDE

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ACKNOWLEDGEMENTS

Commerical Greenhouse Cucumber Production in Alberta was prepared upon recommendations of the Protected Crops Advisory Committee and the Alberta Greenhouse Growers' Association. The production information presented is mainly based upon the experience gained at the Alberta Horticultural Research Center. Information has also been utilized from the Vegetable Production Guides of British Columbia and Ontario.

Disease descriptions and control recommendations were prepared by Dr. Ronald J. Howard, Plant Pathologist at the Alberta Horticultural Research Center, Brooks, while Dr. Ulf Soehngen, Entomologist, provided the pesticide recommendations. The following specialists reviewed the first draft and gave several good suggestions for improvement for which I am grateful: Dr. John Wiebe, Dr. R.J. Howard, Dr. P.D. Kharbanda and Ms. M. Dykstra, Alberta Horticultural Research Center, Brooks; Dr. E.W. Toop, Professor of Horticulture, University of Alberta Edmonton; Mr. Paul Sproule, Mr. Allen Schernus and Mr. Ron Marchuk, Olds College, Olds.

This is the first edition of a publication which we hope will be revised every two years.

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November 1984

INTRODUCTION

Growing plants out of season when outdoor conditions are unsuitable is the basic reason for growing in protected environments, and that is the reason for building greenhouses. Primary considerations are satisfactory plant growth and economics. Natural light conditions will affect plant growth and are the single most important factor which should be taken into account before deciding on the type of vegetables to be grown.

The province of Alberta stretches from 49° north to 60° north and the winter light conditions vary from south to north. Light is critical and a limiting factor for the production of greenhouse vegetables during winter, but during summer there is an overabundance of light. Consequently shading is required. A comparison of solar radiation at Suffield, located just above 50° north, and Edmonton located above 53° north shows that Suffield gets 13.0% more light annually than Edmonton. A further comparison of solar radiation for various seasons indicates that Suffield gets 28.0%; 12.0%; 18.0% and 33.0% better light respectively for the winter period, spring period, summer period and fall period.

This means that during the period of most limiting light, the differential between Suffield and Edmonton is high in terms of both hours of sunshine and available solar energy. Conversely, in spring and summer, when plant growth is least limited by light, the differences between Suffield and Edmonton are reduced but still significant. Adjustments in planting schedules are therefore necessary. Schedules are suggested for various areas in Alberta in appropriate sections.

GREENHOUSE ENVIRONMENT

A greenhouse is a structure designed to control the conditions surrounding plants. These conditions include the light falling on the leaves, the temperature and moisture of both soil and air, the nutrient elements available and the diseases and insects that attack the plants. Factors like heat, water, nutrients and diseases can be controlled but nothing can be done to control light. Artificial light can seldom be added profitably because of cost.

The Effect of Temperature

The temperature of a plant regulates the rate at which all the growth processes proceed. Each plant has an optimum temperature for growth, which varies from crop to crop. For example 12-15°C is highly favorable for the growth of lettuce, but too low for cucumbers.

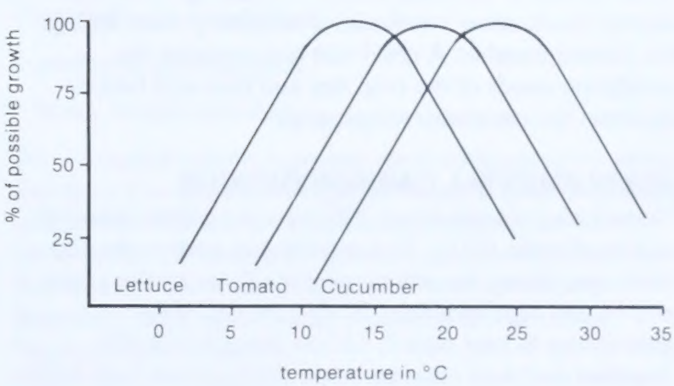


Figure 1. Idealized growth curves for several crops with changing temperature

Figure 1 is a diagrammatic illustration of the growth curves of several crops. These growth curves are idealized, but demonstrate that a temperature favorable to one crop may be entirely unsatisfactory for another.

The temperature in a house must not fluctuate too widely from the optimum or growth will be reduced. Also, with rapid temperature changes there is danger of condensation on the leaves and an increase in leaf diseases.

A living plant constantly uses food in its respiration. The rate at which food is consumed rises with temperature. Figure 2 shows the type of curve obtained with most plants.

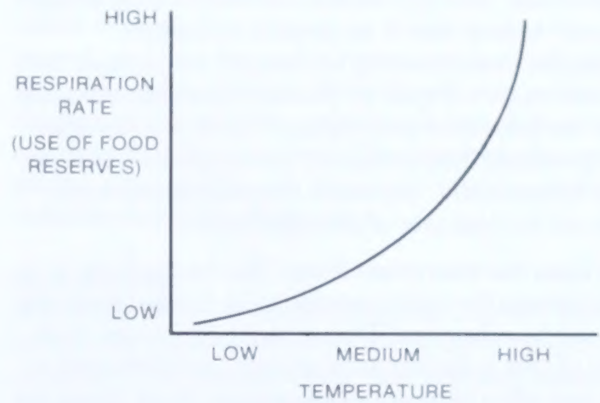


Figure 2. The effect of temperature on respiration rate

Lowering the temperature conserves the food reserves in the plant.

A green plant while in the light is using food but at the same time is producing new food through the process called photosynthesis. The speed at which food production goes on is also controlled by temperature. However, the type of curve is different, as shown in Figure 3.

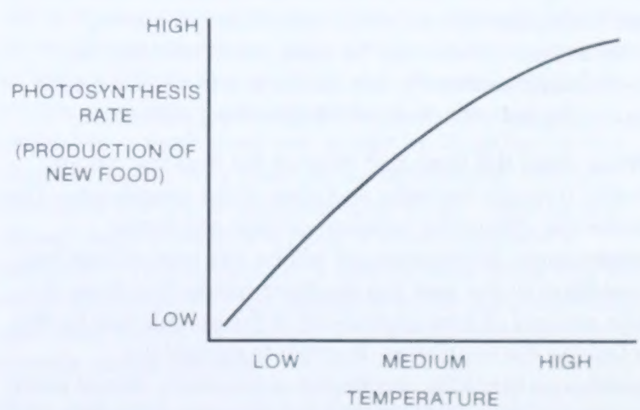


Figure 3. The effect of temperature on photosynthesis rate

Since no food is produced at night the temperature should be lowered somewhat. In this way the food produced during the day is conserved by reducing night time respiration. If temperatures are kept high at night, or during dull weather, spindly, soft plants result. Lowering the night temperature benefits the crop and results in a considerable fuel saving.

The respiration and photosynthesis curves vary somewhat for different plants, but the general pattern is the same for all species. In each case at a low temperature only a small amount of new food is produced, and only a small amount consumed, leaving little or no surplus. At medium temperatures (corresponding to optimum temperature for the several crops in Figure 1), photosynthesis has increased sharply but respiration only slightly. This means that more food is produced than consumed and a reserve is built up. At high temperatures, respiration rises rapidly and soon cancels out the high rate of photosynthesis.

Where does the heat come from? The energy from sunlight shining through a greenhouse is trapped inside the house and becomes heat. During bright days a very large amount of heat is derived from sunlight, and getting rid of excess heat often becomes a real problem. Even during the shorter and duller days of winter a substantial part of our daytime heating is done by the sun.

Artificial heat must be supplied to the greenhouse especially at night. Heat must be moved from a source (coal, oil, or gas boiler) to the air and soil around the plants. The most common heating system is a gas-fired steam boiler with pipes carrying the steam along the outer walls and above or among the plants. Air moves over the pipes, and carries heat with it, upwards and then among the plants. Many different pipe layouts are used to improve heat distribution. In very wide houses pipes may be led along the house near the ground and away from the walls. Sometimes a portion of the heating pipes is placed above the crop and a few greenhouses are equipped with electric fans to circulate the air and to speed up the heating process. Any system may be used which will heat the whole house uniformly, the choice of a particular system depending on economic and engineering difficulties.

Where does the heat go? Most of the heat loss occurs directly through the walls and glass of the greenhouse. The greater the difference between outside and inside temperatures, the more rapid will be this type of heat loss. In addition to the heat lost by direct conduction there is a large amount of heat carried out of the greenhouse by the air leaving the ventilators. In order to control the greenhouse humidity, ventilation is necessary almost every day. As the air moves through the greenhouse it picks up heat and water and carries both away.

Temperature control In order to control temperature it is absolutely essential to have a thermometer in each house. The thermometer should be placed at plant level, and should be moved as the plants grow. At planting time the thermometer should be hung about one foot above ground. As the plants become taller it should be raised until it is at eye level. Temperatures often vary in different parts of the house. For example, when steam or hot water is passing through the heating pipes, the plants near the pipes will be warmer than in the centre of the house. When the pipes are cold, plants near the wall may be colder than those in the centre. Many houses also have cold spots that tend to be several degrees cooler than other parts of the house.

Automatic temperature controls are fairly expensive to install but they relieve the operator of much work and are always on the job. If automatic controls are not used, the operator must check the thermometer frequently. It is impossible to feel the temperature of a house accurately, so do not depend on how the air feels.

Whether the temperature control is automatic or manual there are still two alternative methods of control: the operator may change the amount of ventilation, or he may change the amount of heat being supplied to the house. In order to reduce humidity and to maintain good carbon dioxide levels some ventilation is necessary, even during the coldest weather. A good rule is to consider the ventilation needs of the crop first and then add heat to maintain the necessary temperature.

SUPPLEMENTAL CARBON DIOXIDE

Normal air contains about 300 parts per million (ppm) of carbon dioxide (CO_2). In a greenhouse, carbon dioxide levels rise during the night owing to release by the plants and by soil organic matter. During the day, if the greenhouse is kept closed, carbon dioxide is rapidly depleted and may often be below 200 ppm on fairly bright days. This is the point at which carbon dioxide addition is most important, however, research has shown that greenhouse crops will almost always be improved if carbon dioxide levels are raised up to 1000 to 1500 ppm. The level to which the carbon dioxide concentration should be raised is dependent on the crop, light intensity, temperature and growth stage of the crop. Carbon dioxide is taken up by the plant through pores in the leaves. These pores will close if the plant is under water stress or if temperatures are excessive. Addition of carbon dioxide under either of these conditions is of no benefit since photosynthesis occurs only during daylight hours; carbon dioxide addition is not required at night. Supplementation should start approximately one hour before sunrise and the system should be shut off one hour before sunset.

When ventilators are opened it is not possible to maintain high carbon dioxide levels, and carbon dioxide generator should be shut off when vents are open more than 20 percent. Carbon dioxide can be obtained by burning natural gas, propane or pure carbon dioxide is available in cylinders.

GENERAL PRODUCTION INFORMATION

Management

Greenhouse management involves:

- a maintenance program (electrical mechanical)
- sanitation and sterilization practices
- proper crop scheduling
- seedling health care
- transplanting
- nutrient/fertilizer preparation
- analysis of growing media at regular intervals
- crop maintenance — pollinating, pruning, training and harvesting
- pesticide scheduling application
- packaging and marketing
- personnel management
- timely trouble shooting.

For successful culture, a grower must understand the above mentioned management aspects. Timely trouble shooting is important. Assistance in diagnosing problems can be obtained by contacting the greenhouse crops specialist at the Alberta Horticultural Research Center, Brooks or Regional Crops Laboratories located at Brooks, Olds, Vegreville and Fairview.

GREENHOUSE SOIL MANAGEMENT

Type and Condition of Soil

Most of the greenhouse vegetable crops in Alberta are grown in soil. Because of disease problems, growers are switching over to container growing. The main purpose of the soil is to provide a medium in which there is a proper balance between air, water and nutrients. If this balance exists the roots will easily obtain their requirements of water and nutrients and growth will be rapid.

A greenhouse soil should be a sandy loam with a high organic matter content if at all possible. A fine textured or heavy soil tends to compact easily. It also stays wet during long periods of cloudy weather. In contrast, in a sandy soil both air and water move freely and compaction is slight, so roots can grow through the soil more easily. Almost any soil can be made suitable for greenhouse production by proper management. Any soil, either in the greenhouse or in the field before being brought into the greenhouse, can be improved by adding organic matter. It should be kept in mind that the organic matter is being added as a soil conditioner primarily, and not so much for its nutrient value. It takes several years to change the condition of a soil and the addition of organic matter to the soil should be a continuing process.

Both light and heavy soils can be improved by organic matter. Heavy soil is opened up, that is, made more porous, and very light soil is better able to absorb and hold water and plant nutrients. When the soil is in proper condition it will hold the optimum amount of air, water and nutrients all at the same time. The organic matter assists greatly in keeping the soil loose and in holding water and nutrients in reserve for the plant.

Soil Testing

Before planting greenhouse vegetable crops it is advisable to have the soil tested in order that nutrient levels can be adjusted to the required levels. After planting, soil tests should be done at regular intervals.

How should a soil sample be taken? As only a small amount of soil is required for testing, it is important that the sample truly represent the composition of all the soil in the area to be tested. To ensure this, take a number of samples from several areas of each house and bulk them. Then mix these sub-samples and take out the amount to be sent away. If the area is large and different soil textures are encountered, several samples should be sent. Samples should be taken at depths of 15-30 cm. It is preferable to dry them overnight before shipping. The final sample sent in for analysis should weigh from 200-500 g after drying.

When should a soil test be done? A test should be done immediately after a crop is removed. The results of this test will determine the nature and quantity of preplant fertilizers or manure to be used. A second test should be done two to three weeks before planting and after soil sterilization (steam or chemicals) has been done. In the case of cucumber, a weekly soil test should be done for the first four weeks and on a monthly basis thereafter. Fertilizer schedules should be modified accordingly. A soil sample should also be taken whenever a fertility problem is suspected in a greenhouse. It usually takes about one week to get results back to the grower from the Agricultural Soil and Feed Testing Laboratory. Private laboratories may provide results quicker.

How and where should a soil sample be sent? Sample boxes are available from your local district extension office. Fill in the green information sheet to facilitate fertilizer recommendations. Samples can be mailed through your district extension office or directly to the Agricultural Soil and Feed Testing Laboratory, O.S. Longman Building, 6909 - 116 Street, Edmonton, Alberta T6H 4P2. Greenhouse soil samples receive priority and are analyzed in a different manner from field samples. It is very important, therefore, to identify them by filling in the greenhouse soil information sheet and labelling the containers as greenhouse soil samples as well, especially if they are sent under separate cover. Make sure that the requested information is also provided. It will help to make proper recommendations.

Private soil testing laboratories have their own containers. The addresses are given on page 42. Please contact these laboratories directly for cost and sample information.

Explanation of soil test values. Table 1 summarizes the accepted good fertility levels for most greenhouse crops. Specific recommendations for balancing nutrients, correcting pH and improving soil texture are made for each soil sample sent to the Agricultural Soil and Feed Testing Laboratory. The recommendations are made by the greenhouse crops specialist at the Alberta Horticultural Research Center, Brooks. As different laboratories use different extraction procedures, it is therefore likely that recommended nutrient levels will differ between laboratories. The Agricultural Soil and Feed Testing Laboratory uses water extraction procedures.

Table 1. Recommended fertility levels for a growing medium used for greenhouse vegetable production

Ammonium nitrogen	0-20
Nitrate nitrogen (ppm)*	35-180
Phosphorus (ppm)	5-50
Potassium (ppm)	35-300
Calcium (ppm)	60-400
Magnesium (ppm)	30-200
Sodium (ppm)	0-30
Sulfates -S, (ppm)	30-60
Nitrites (ppm)	nil
Chloride (ppm)	nil
Free Lime	trace
pH	5.5-6.9
Electrical Conductivity (mmhos/cm^2)	0.8-3.0

* *Parts per million water extractable nutrients and salts in soil.*

PRECROP APPLICATION OF FERTILIZERS, STRAW AND MANURE

Application of Fertilizers

A soil test must be made before deciding on any precrop application of fertilizers. In general, less soluble fertilizers such as superphosphate should be incorporated. Nitrate and potassium are best applied at the time of planting.

Table 2. Suggested precrop fertilizers

Fertilizer	Major nutrients supplied	Effect on pH	Approximate rate
Superphosphate 0-20-0	Phosphorus Calcium Sulfur	no change	25 kg/100 m^2
Gypsum*	Calcium Sulfur	no change	25 kg/100 m^2
Potassium sulfate 0-0-50	Potassium Sulfur	no change	10 kg/100 m^2
Ground limestone*	Calcium	Alkaline	25 kg/100 m^2
Dolomite limestone*	Calcium Magnesium	Alkaline (slow acting)	25 kg/100 m

* *Use exact rates as determined by a soil test.*

Application of Straw

Straw is incorporated in soil to provide organic matter and to improve soil structure. Straw helps to loosen the soil and improve aeration. Wheat and barley straw are commonly used. Use ten bales/100 m^2. A bale is generally 18 kg in weight. Straw should be well chopped up before incorporation. Straw can also be used as a mulch in growing beds to reduce weed development and diseases when for instance tomato crops are layered on the ground. Be sure that the straw is not contaminated with herbicide residues.

Decomposition of straw is a gradual process and extra nitrogen should be added to facilitate this process. If extra nitrogen is not added, the growing plants and decomposing straw will compete for available nitrogen.

Use of Manure

Well rotted manure can be incorporated as an organic amendment and also as a source of potash and other nutrients. Manures are generally very high in salts like sodium and chloride. It is, therefore, very important that manure be analyzed **before application** and another soil test taken after incorporation. If sodium and potassium are above the recommended levels, leaching is recommended. CAUTION: If the growing medium is high in salts and the water is high in sodium, then plant damage can occur as a consequence of the use of manure.

SOIL pH AND ITS CORRECTION

The term pH means the degree of acidity or alkalinity of the soil or growing media. It is measured on a scale of 0-14 with 7 being neutral. The availability of many nutrients, especially micronutrients, is affected by the pH of the growing media. Cucumber, tomato and lettuce plants grow best at pH 6.0-7.0. In soilless mixes the pH range is between 5.3 to 6.5

The safest way to reduce pH is the preplant incorporation of acidic peatmoss in growing beds. Incorporate peatmoss in the top 10-15 cm of beds. Besides reducing pH, peatmoss application will help in the dilution of higher soluble salts.

Other precrop treatments to reduce alkaline pH are

1. Finely ground sulfur — 4 kg 100 m^2
2. Aluminum sulfate — 5 kg 100 m^2
3. Iron sulfate — 5 kg 100 m^2

The application rates will reduce the pH by approximately one unit. Ground sulfur is the most commonly used. Its effect on pH becomes evident three to four months after application and generally will last for one to two years.

When the growing medium is acidic such as in prepared mixes, lime application is required. Use Table 3 as a guideline for applying lime.

Table 3. Preplant lime application for pH adjustment to 7.0 (neutral)

	Soil texture			
	Sands —	Loams — silty clay — loams	Clay — loams — clay	Organic
	Kilograms of ground limestone required per 100 m^2			
Soil pH reading				
4.0	—	—	—	500
4.5	—	—	—	450
5.0	—	—	—	350
5.6	62.5	100	250	300
6.0	50.0	75	200	250
6.4	30.0	50	150	175
6.8	10.0	20	50	75

The above recommendations are made in terms of ground limestone. Dolomite limestone may be substituted at par.

It is advisable that growers conduct their own lime requirement test and allow for reaction time. Such a test can be conducted by analytical laboratories.

Incorporating limestone into the soil does not change the pH immediately. The pH of some greenhouse soils may rise slowly for weeks after such an application. In some areas of the soil the pH will change as soon as the limestone becomes moist. Hence, the root may pass through zones differing widely in pH, absorbing the desired available nutrients from each zone.

Hydrated lime generally should not be used in greenhouse soil. It is much more reactive than limestone. Ammonium nitrogen is absorbed on the soil complex and hydrated lime may displace it in quantities sufficient to damage roots. Hydrated lime also increases soluble salts, often to dangerous levels. Furthermore, the rapid change in soil pH is seldom desirable. In the few instances where a crop is detected growing in an extremely acid medium, hydrated lime may be suspended in water at 1 kg 45 L and applied at 200 L/100 m^2. This should be followed by an application of limestone to further correct the pH, assuming that the hydrated lime will have raised the pH 0.5 units.

Sphagnum peat moss is widely used in preparing various growing media. Its pH may vary from 3.0 to 4.5. As a general rule, 4 kg of dolomite limestone should be used for each cubic metre of peat as it comes from the bale. If the pH of the peat is below 4.0, increase limestone to 5-6 kg/m^3.

ADJUSTMENT OF SOIL pH IN A STANDING CROP

An alkaline pH may result during crop growth because of the continued use of basic fertilizers such as calcium nitrate (15.5-0-0). Phosphoric acid or sulfuric acid at 3-6 mL/100 L of water should correct this problem. If a constant feed program is followed, use a double head injector to feed acid separately. Never mix fertilizers with acids as precipitation will occur. If a weekly feeding program is followed use acidified water in between feedings.

The soil pH can also be controlled during cropping by using acidic fertilizers. Refer to the section on fertilizer management. Consult the section on water quality. Potassium hydroxide (KOH) can be used to bring the pH to normal levels, when peat-based media show an acidic pH.

APPLICATION OF GYPSUM FOR CALCIUM

It is desirable to maintain adequate levels of calcium. The usual practice is to make enough of it available before planting. In soils where the calcium level is low but the pH is satisfactory, calcium sulphate (gypsum) may be used instead of calcitic limestone. Generally 75-25 kg/m^2 of gypsum will be required when the test ranges are between 100-400 parts per million of calcium.

STRAW BALE CULTURE

The use of straw bales often makes it possible to grow cucumber crops under conditions where cultivation might otherwise be very difficult, such as where the soil is cold or heavy, or is infested with pathogens. In Alberta, straw bale culture has been used successfully to grow crops on nematode infested soils.

There are many advantages to straw bale culture. Straw bales provide a disease-free, well-aerated rooting medium and their use reduces the need for soil sterilization to control diseases. During fermentation of the straw, heat is produced directly under the plant roots and carbon dioxide is released. Both the extra heat and the carbon dioxide enhance plant growth.

Preparation of the bales involves the application of water and fertilizers to enhance fermentation of the straw. To initiate fermentation, greenhouse temperatures should be approximately 18°C. The following schedule has proven successful for preparation of straw for use on cucumbers.

Table 4. Bale preparation schedule

	Days										
Fertilizers*	1	2	3	4	5	6	7	8	9	10	11
Ammonium Nitrate (34-0-0)	HEAVY			140 g	water to soak bale		70 g			70 g	
Super-phosphate 0-20-0	WATERING			0			0	water to soak bale		450 g	Water in, apply top-cap and plant
Potassium Nitrate 13-0-44	DAILY			0			0			370 g	

* *The weight of fertilizer suggested is for 18 kg bales of straw.*

The superphosphate and potassium nitrate may be omitted from the preparation treatment. However, the plants planted on those bales must be fed with readily available phosphate and potash much earlier than if these nutrients had been applied to the bales.

For planting, a small amount of growing medium (so called top-cap) is put on the bales just deep enough to take the ball of roots. This medium may be made of various materials, but the most suitable appears to be peat, thoroughly soaked and neutralized with limestone (about 9 kg of ground limestone per bale of peat). A mixture of equal parts sterilized soil, peat and sand has also proved successful. If the bales are set into a shallow trench about 15-20 cm deep, the soil dug out of the trench may be used as a top-cap, provided it is well structured and free from pests and pathogens. Some growers steam sterilize this soil top-cap and bale together.

The management of a crop growing on straw is more critical than of one growing in soil. More frequent watering and earlier and heavier feeding are required. Regular tissue tests are recommended to monitor the nutrient levels. When peat moss is used as a top-cap, use the fertilizers suggested in individual crop sections.

SOILLESS CULTURE

Cucumbers can be successfully grown in inert media such as peat, peat + vermiculite, peat + perlite, sawdust, bark chips, sand, etc. Such media require more detailed pre-crop preparations than soil. Good results are obtained by adding limited amounts of fertilizers.

Table 5 shows the formula for one mix which can be used for satisfactory crop production. Such a mix can be used more than once and can be steamed to eliminate pathogen infestations if necessary.

Table 5. Peat-vermiculite mix

	1 cubic metre
Peat (sphagnum)	0.49 m^3
Horticultural vermiculite	0.49 m^3
Dolomite limestone	5.90 kg
Superphosphate 0-20-0	1.20 kg
Potassium nitrate (13-0-44)	0.90 kg
Chelated iron	37 g
Borax (sodium borate)	37 g
Fritted trace elements	110 g

Fluff the baled peat before mixing. Mix very thoroughly. Calcite limestone can be used instead of dolomite, but then add magnesium sulfate at 3.0 kg per m^3.

The cucumber crop may be grown for three to four weeks on this mixture without feeding. After that period the constant feeding program suggested in the fertilizer section should be followed. Adjustments according to regular tissues analyses should also be made.

SOIL MIXES FOR SEEDLINGS

Many different composts and mixes have been tested and proposed for the growing of cucumber seedling transplants Commercial soilless media have proven to be successful in raising healthy, uniform seedlings.

You can make your own mix as well. The following are two mixes which give good results. After you have prepared these mixes, do get them analyzed. It never hurts to know the composition of your mixture.

Soil Mix One Cubic Metre
0.59 m^3 sandy loam
0. 26 m^3 peat moss
0.15 m^3 coarse silt free graded sand
0.60 kg, 20% superphosphate
If pH is below 6.0, add 1.2 kg calcitic limestone

Soilless Mix One Cubic Metre
0.55 m^3 peat
0.44 m^3 vermiculite
1.20 kg calcitic limestone
1.20 kg dolomitic limestone
0.60 kg 20% superphosphate
0.60 kg potassium nitrate with micro-nutrients
18.5 g borax

NOTE: 1 m^3 = 1000 L

GREENHOUSE SANITATION

Proper sanitation is very important in controlling various diseases and pests in a greenhouse. Remove crops promptly from the greenhouse at the end of the cropping season. If plants are left to decay pest and disease levels may build up and survive until the next crop. If pests or diseases are at a high level it may be advantageous to fumigate the greenhouse with the plants in place to prevent the dispersal of pests during their removal from the greenhouse.

Between successive crops, spray the greenhouse interior, walkways, training wires, gutters and tools with household bleach at a rate of 5 L 100 L of water or with commercial available formaldehyde at a rate of 2.5 L 100 L of water. Formaldehyde can be used as soil and space fumigant as well, when mixed with potassium permanganate. Be sure the formaldehyde is at room temperatures. The formaldehyde is placed in heat resistant containers, (no more than 1 L to a 9 L container) add 188 g of potassium permanganate to treat 56 m^3 of greenhouse space.

Be careful when adding the permanganate as the reaction may be violent. Use of a gas mask with a full face plate and a canister rated for organic vapors is recommended during the start of the procedure. Keep the greenhouse closed for 24-48 hours. Ventilate well before reentry.

Weeds in the greenhouse and in the surrounding area are a continuous source of mite, aphid, whitefly and thrips. Use a contact weedkiller such as Gramoxone (paraquat) to kill outside weeds. Proper sterilization of greenhouse soil should reduce or eliminate weed problems from the greenhouse. Remember — most of the soil sterilizing chemicals will destroy germinating weed seeds only.

Soil Sterilization

To prevent severe losses caused by soil borne diseases and nematodes, it is necessary to destroy as many of the causal organisms as possible by steaming or fumigating the soil between crops. Steam, if properly applied, will kill all living organisms in the soil and is still the most effective means of sterilization. However, with increasing fuel costs, chemical fumigation may appear more attractive.

The following rules must be followed to achieve satisfactory results:

1. The soil temperature at 15 cm depth must be 13°C or higher for successful treatment with chemicals.
2. Soil must be in a loose condition so that penetration is complete. Sods, lumps and organic materials must be thoroughly broken up.
3. If organic materials (compost, manure, etc.) are to be used, they must be incorporated before treatment so that recontamination does not occur.
4. If straw is added, it must be well chopped and well decomposed before chemical fumigation.
5. The soil must be moist, but not wet.

When soil is sterilized with steam or fumigated with chemicals, the number of soil microorganisms is greatly reduced for the first few days, then it rises and eventually exceeds that of untreated soil. The first organisms to return after treatment meet no severe competition. Thus, if plant pathogens are among the first to recolonize the soil, they may develop rapidly and cause severe disease losses. It is, therefore, important that every effort is made to prevent disease organisms from gaining entrance to the soil. Pathogens can gain entrance to the soil by 1) splashing water; 2) infested cuttings; 3) soil in water hose; 4) infested containers; 5) infested tools and equipment; 6) grower's hands and foot wear; 7) placing containers on ground; 8) unsterilized covers; 9) infected plants or seeds. The wilt causing fungus *Fusarium oxysporum* can reestablish itself from spores in the air.

Soil Steaming

Use steam at a pressure of 48-83 kPa. It is important to maintain a soil temperature of not less than 80°C for 30 minutes throughout the soil, or in ground beds to a depth of 36 cm. Use an accurate thermometer. To establish this level of uniform temperature may require four to eight hours, depending upon the soil texture. The most commonly used method of steaming is to cover the beds with a tarp and release steam inside. The penetration of steam is not very good. The best method is to apply steam through a network of drain tiles. Such tiles should be laid approximately 60 cm deep, at 60 cm intervals with a 5 cm layer of gravel at the top. Steaming through drain tiles can achieve good penetration to control nematodes.

Particular care must be taken to adequately heat the soil adjacent to footings of walls, support poles and other underground structures. Escape of steam through blowholes in very loose, dry soil, e.g., near heating pipes, should be prevented.

Avoid over-steaming. Try to ensure that the temperature does not exceed 95°C in any portion of the treated area. Undesirable effects of oversteaming include: a) excessive ammonia release; b) manganese toxicity; c) increased total salts; and d) destruction of organic matter. Leaching is usually required after steaming. Do not use ammonium fertilizers for at least two months after steaming because of low populations of nitrifying bacteria which convert ammonium to nitrate nitrogen.

Soil Fumigation

Some fumigants control fungi, bacteria, nematodes, insects and weeds, whereas others which are more specific in their action control only nematodes or fungi. Soil fumigation is not always an adequate substitute for soil steaming. Fumigants do not destroy all soil-borne viruses harbored in root debris and other plant parts.

For fumigation of soil in bulk piles or stacked flats use cans of methyl bromide + chloropicrin (MC-2 or MB-C_2) at 0.3 kg/m^3.

Fumigants listed below are effective as preplanting treatments for greenhouse soil beds. Unless otherwise stated AMOUNTS ARE FOR 100 SQUARE METRES. Do NOT apply fumigants when the soil temperature is less than 13°C. Ensure that all traces of the fumigant have escaped from the soil before seeding or setting transplants. To check this, set a few plants in the soil a few days before planting would normally begin, and watch their reaction. Always follow manufacturer's directions very carefully.

To control fungi, nematodes, insects and some bacteria:

Basamid: It is available in granular form (10% active ingredient). Distribute 2-4 kg/100 m^2 evenly on the soil surface. This may be done by hand when wearing rubber gloves or by means of a fertilizer spreader. Incorporate to a depth of 15-20 cm and seal the soil by watering, packing or covering with plastic sheets. The soil must be aerated before planting. The amount of time for fumigation and aeration depends on soil temperatures. Fumes from Basamid when released from the soil will be harmful to plants in a greenhouse atmosphere.

Vorlex: It is available in liquid form and has to be injected into the soil at a depth of 30-40 cm. Most growers have an injection system of their own mounted behind a rototiller. Use a rate of 6 L/100 m^2. After injection, seal the soil surface as for Basamid treatment.

Other fumigants are:

Methyl Bromide + Chloropicrin

- pressurized cans containing 98% methyl bromide + 2% chloropicrin 7.5-10 kg
- injectable containing 67% methyl bromide + 31.8% chloropicrin 2.5-3.65 kg per 100 square metres (250-365 kg per ha)

CAUTION — Methyl bromide is a liquid which forms a poisonous gas when released from its container. The chemical is so poisonous to man and livestock that it must be applied with extreme caution and only by applicators who are specially licensed to use this type of fumigant. It must be used under a gas-proof cover, usually plastic. The licensed applicator must make the property owner and all assistants aware of all the precautions that must be taken when using this material. Before using, read the label carefully, wear the correct protective equipment (page 32) and read the section in the Pesticides Act, Alberta Regulations, which deals with methyl bromide soil fumigation. Also see licensing requirements for methyl bromide.

To control fungi, bacteria and certain stages of insects: Formaldehyde (1 L of 37% formaline in 30 L water) 1200 L.

Nematodes

Nematodes are microscopic worms which feed on roots. Nematode activity can increase the severity of soil-borne diseases such as those caused by *Fusarium* sp. Pathogenic nematodes cause knots to develop on the roots of cucumbers and tomatoes, reducing plant vigor and ultimately causing wilting and death of the plant. A number of species are not harmful and may cause no apparent injury to the plant roots.

Nematodes may be spread by movement of contaminated soil into or within the greenhouse, or by using contaminated tools. In many cases, nematodes are present in the soil when the greenhouse is established.

Hence, control measures should be taken before the first crop is planted.

Proper soil pasteurization with steam or chemicals can help in controlling nematode infestations. As root knot nematodes are known to move downward in the soil, pasteurize immediately after removing the crop. Steaming from the top is generally effective in killing nematodes in the top 15-24 cm of the soil. This will delay the onset but will not eliminate nematode attack. Another practical way of growing crops in nematode infested soils is to use straw bales. Nematodes cannot move in a medium like straw bales. If nematode-infested greenhouse soil is used, then steam it after placing it on the straw bales. Growing in plastic bags using ready-made mixtures or sawdust is another method.

Damping-Off

This disease causes the seed to rot in the soil or the death of seedlings before or after emergence. The stem at soil level becomes water soaked and turns black or brown. Shrivelling of the tissue may follow.

Control measures include

- use sterile media for growing seedlings
- grow a bigger seedling in a 12-15 cm pot
- treat seed with fungicides such as captan-vitavax mix or thiram
- use warm water on recently transplanted seedlings. Water early in the day. Allow soil surface to be on dry side overnight.
- provide good air movement.

WATER QUALITY

Large quantities of water are used in a greenhouse for irrigation and fertilization. Have your water analyzed through your nearest district extension office. Ask for an analysis for irrigation purposes, along with an additional analysis for boron. Send a copy of the analysis to the greenhouse specialist at the Alberta Horticultural Research Center, Bag Service 200, Brooks, Alberta T0J 0J0, for interpretation of the results. The following broad guidelines can be used in the interpretation of water quality.

1. Electrical Conductivity (EC) of the water: For waters having a Sodium Absorption Ratio (SAR) of less than 6.0:
   - water with an EC of 0.8 mmhos/cm or less is considered suitable for irrigation of cucumber, tomatoes and lettuce, under normal use conditions
   - water with an EC between 0.81 and 2.2 mmhos/cm is considered usable for irrigation, but only when accompanied by special management practices
   - water with an EC above 2.2 is not recommended as the sole source of water for irrigation. Consider collecting rain water from the roof of your greenhouse to mix with such water.
2. Special Management Practices:
   - provide adequate drainage
   - never allow the growing medium to become more than moderately dry. Maintain a higher moisture level in the rooting zone of plants than would be necessary with higher quality water. Reduce stress by designing a well drained mix.
   - analyze soil samples periodically to monitor the salt level
   - leach periodically to remove excess salts from the medium. Use the following table as a guideline

EC of water mmhos/cm	Parts per million salts (ppm)	Leaching requirements %	Recommended leaching interval	Interpretation of water quality
0.35	245	5.0	12 weeks	excellent
0.40	280	6.0	9 weeks	very good
0.60	420	7.5	6 weeks	good
1.00	700	12.5	4 weeks	fair
1.40	980	17.5	3 weeks	permissible
1.80	1280	22.5	2 weeks	permissible
2.20	1540	27.5	1 week	excessive — too salty

- water with an EC of 2.3 mmhos/cm or higher is normally not suitable for irrigation except when it can be mixed with good quality water, e.g., rain water.

Acidifying Water Supplies

Most of the water in Alberta cities is alkaline and moderately hard — it contains moderate amounts of calcium and magnesium. However, most rural water supplies are soft in nature, that is, they contain moderate or large quantities of sodium. Soft water or chemically softened water is not suitable for growing plants.

Hard water can be used for growing plants, but calcium can result in several problems all of which can be alleviated by acidifying your water supply. Remember water pH will also affect the activity of chemical sprays. Many chemical sprays remain active longer in lower pH solutions than in high pH solutions.

The calcium in Alberta water supplies is largely in the form of calcium carbonate or bicarbonate which precipitates out as the familiar white deposit of calcium carbonate. The continued use of hard water for irrigation can lead to an accumulation of calcium in growing media, unless it is leached out by heavy nitrogenous feeding. When hard water is used for misting purposes, it can leave white scales on leaf surfaces, reducing photosynthesis.

Carbonates and bicarbonates interfere with the absorption of fertilizer as the amounts of these materials in the water become greater. Generally there are few carbonates in water until the pH of the untreated water is above 8.3, but carbon dioxide in the air dissolves in water and makes bicarbonates with various minerals in solution. Acidification of the water with phosphoric or sulfuric or nitric acid is a means of overcoming the injurious effects of carbonates or bicarbonates by neutralization. Do not add acid to the fertilizer concentrate tank. Contact the greenhouse crops specialist at the Alberta Horticultural Research Center, Brooks, for calculating the exact amount of acids needed. General guidelines are given below.

Phosphoric Acid

This acid can be added through a fertilizer injector. An injector with two heads is suitable. Use injector heads meant for acids. An analysis of the water in terms of carbonate hardness is needed and can be obtained by subtracting noncarbonate hardness from total hardness.

In Alberta generally 2-6 mL/100 L of 85% phosphoric acid is adequate for pH control.

Nitric Acid

Concentrated nitric acid (70% w/w) can also be used. It also provides some nitrogen feed helping to offset the cost of applying the acid. For each 1000 mL of concentrated nitric acid added to 1000 L of water, you are supplying 220 ppm of nitrogen.

To assess accurately the amount of nitric acid required for your particular water supply, please send a water sample to the greenhouse specialist, Alberta Horticultural Research Center, Bag Service 200, Brooks, Alberta T0J 0J0. An easy way is to send it through your district extension office.

A typical graph shown below is from a water sample containing 100 ppm of calcium. Here 275 mL of concentrated nitric acid are required to bring the pH to 5.9. This will also provide 60 ppm of nitrogen.

NOTE: This graph is an example only. Your water sample should be assessed individually.

Remember concentrated acids are dangerous chemicals and must be handled with care. Always add acid to water not water to acid. Acidified water is corrosive and may eat away the metallic components of your irrigation system.

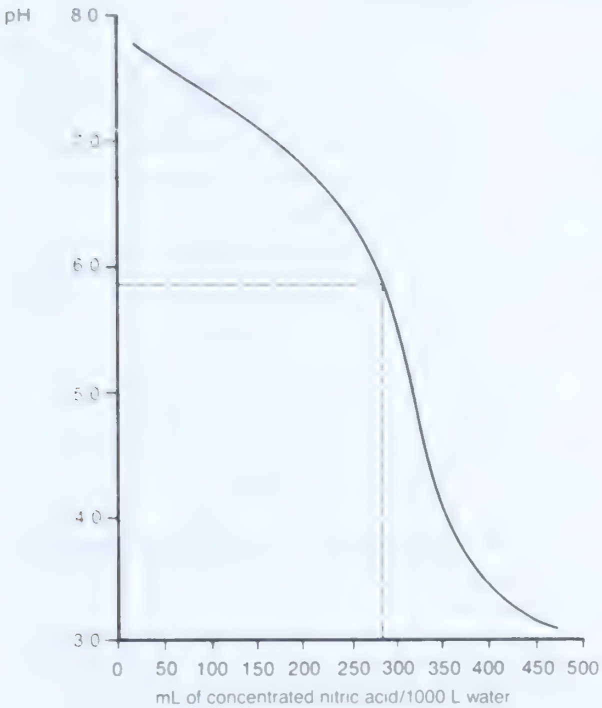


Figure 4: The effect of adding acid on the pH of a water sample

Sulfuric Acid
Sulfuric acid can also be used to lower the pH of water. The amount has to be calculated based upon your water quality. If sulfates are more than 100 ppm then the use of sulfuric acid should be avoided.

Hydrochloric Acid
The use of hydrochloric acid should be avoided because of its chlorine content.

Chlorination
Chlorination of city water to reduce the population of various microorganisms is accomplished by dissolving chlorine gas under pressure in the water. The amount that will go into solution is relatively small, and even though there may be a residual chlorine taste or smell, the water is safe for plants

Fluoridation
Fluoridation of water is common in many cities in order to minimize tooth decay in children. When water is fluoridated, sodium fluoride is added to provide about three parts per million of fluoride in the water. The fluoride content does not hurt cucumber plants.

Boron
Boron is a fertilizer element which occasionally occurs in such quantities in Alberta water supplies as to be phytotoxic. When the level of boron is one or more parts per million, the water is considered unsatisfactory for use. There is no inexpensive method of removing boron and an alternative source of water must be considered.

Sodium
Sodium is another element which is usually present in well water throughout much of Alberta. It is not required for plant growth and can reach levels that are toxic to plants. If sodium is above 100 ppm, reverse osmosis should be considered to remove it, or an alternative source of water found. Water with up to 100 ppm can be used, if the potassium level is maintained above that and special management practices are followed, e.g., regular leaching, good drainage, etc.

Pollutants
Pollutants of various kinds, some of which are toxic to plants, may be found in certain water supplies. Such materials may have been discharged inadvertently into a stream or buried where it later infiltrated into the ground water. Long lasting herbicides like Picloram (Tordon) can pollute water supplies and cause serious damage to crops. The best means of detection is to conduct a biological test with water intended for irrigation. Grow seeds of tomato and fababeans. Watch for any abnormal growth symptoms such as crinkling of new leaves or abnormal spindly leaves. This can serve as a test of the suitability of your growth medium as well.

SEEDLESS CUCUMBER PRODUCTION

GENERAL INFORMATION

A large number of European seedless cucumber cultivars are available to the grower. Individual cultivars respond differently to a given set of environmental, crop management and growing conditions. Hence a grower must determine for himself which cultivar performs best under his greenhouse conditions. New cultivars should be tried first on a small scale.

All European cucumber cultivars set fruit without pollination and the fruits are seedless. Pollination causes off-shaped fruit, thus bees must be prevented from entering the greenhouse. To help overcome this, all female (gynoecious) cultivars have been developed which bear almost 100 percent female flowers. Male flowers can develop under high temperatures or other stress conditions on some cultivars. They should be removed as soon as they are visible.

Cucumbers are extremely sensitive to environmental factors such as low light, pollutants, cool air temperatures, low humidity, low carbon dioxide and high soluble salts. The success of a cucumber crop is dependent upon close adherence to the environmental and fertilizer needs of the crop.

RECOMMENDED CULTIVARS

Farbio — The fruit has very good green color and is slightly ribbed. Main stem fruit may be short if too many fruits are allowed to develop at the same time. The cultivar should not be pruned drastically. Fruit has a good shelf life.

Corona — The fruit is dark green and ribbed. Excellent shelf life suitable for growth under a slightly lower temperature regime. Plant shows strong growth. There is strong resistance to gummy stem blight and botrytis. Suitable for long season cropping.

Farona — This cultivar has growth characteristics between Farbio and Corona. Strong vigorously growing plant. The fruit is dark green and ribbed.

Profito — This relatively new cultivar is resistant to powdery mildew. Recommended for planting after February 1. Under low light conditions may show leaf necrosis. Fast growing and could produce fruit one week earlier than other cultivars.

Sandra — Fruit is deep green, slightly ribbed, averaging 38 cm in length. Intermediate neck. Resistant to gummosis and leaf spot diseases.

Toska — This cultivar displays good early vigor. Fruit has a good green color. The cultivar can be grown at slightly cooler temperatures.

Several powdery mildew resistant cultivars are now available. They should be tested on a small scale. Contact the greenhouse crops specialist at the Alberta Horticultural Research Center, Brooks, for further information.

SEEDLING PRODUCTION AND TIMING

Either one or two crops of greenhouse cucumbers are commonly produced per year in Alberta. Use the following table as a guideline for spring crops:

General location in Alberta	Seeding date	Transplanting date	Approximate harvest dates
southern Alberta	Dec. 1 to Dec. 25	Dec. 25 to Jan. 20	Feb. 15-30
central Alberta	Jan. 7 to Jan. 14	Feb. 7 to Feb. 14	Mar. 21-28
northern Alberta	Jan. 30 to Feb. 7	Feb. 28 to Mar. 7	April 15-20

The crop can be continued until September, provided diseases and insects are kept under control and plant vigor maintained. For establishing a fall crop, the plants are pulled by the end of July, and a new crop planted by the first week of August. The fall crop may be maintained up until December in southern Alberta; till the end of October in central Alberta and the end of September in northern Alberta.

This arrangement can vary depending on marketing, fuel costs and disease susceptibility.

Carbon dioxide enrichment should be applied throughout the propagation period, and is useful to the plants as soon as the seed leaves are fully expanded. Carbon dioxide enrichment should be at a level of 1000 parts per million. The young plants are tender and easily damaged by excessive levels of carbon dioxide. Well-sealed greenhouses may need a short period of venting or fresh air intake once or twice a day during spring, especially under damp calm conditions. It will reduce the risk of the build-up of toxic by-products of combustion.

ARTIFICIAL ILLUMINATION

Cucumber seedlings are very light-dependent and the vigor and color of their early growth is proportional to the light levels received. Sowings in December and January should always be under the best circumstances. Glass should be cleaned before sowing to allow the maximum light transmission. Artificial lights are not used in Alberta, however, they are commonly used in Europe. Lighting is an expensive operation, and it is not always easy to determine the benefits which result from its use. Lighting techniques vary, as do types of lamp and installation. As a general rule, 12-16 hours lighting in each 24 hours is standard, using illumination levels between 7,500-15,000 lux. Continuous lighting should be avoided because cucumbers may produce an unsatisfactory growth pattern and develop scorches caused by excessive radiation of certain wavelengths. High pressure sodium lamps of 400 or 1000 watts are commonly used. A 400 watt lamp is enough to cover 10 m^2 of growing area.

RAISING HEALTHY SEEDLINGS

Seed Sowing

- select plump seed only
- sow seeds in plastic trays filled with sand, sand-peat or a commercial mix
- maintain the strictest hygiene because cucumber seedlings are very sensitive to root diseases, especially pythium
- space seeds at 2.5 cm square pushed into the compost to 1 cm
- water with a fine hose — despite traditional opinion, there seems to be little significance in the orientation of the seed when it is sown, and a seed placed flat will germinate and emerge at the same rate as one placed on edge or on its end
- maintain a temperature of 27°C. Slow germination produces a poor quality plant, and the aim should be to produce a seedling with fully expanded cotyledons within 48 hours of sowing
- prick-off into moist propagation pots as soon as the cotyledons are fully expanded. Plastic pots, peat pots, walehide pots are commonly used. Pot diameter can range from 12-15 cm according to the stage at which it is intended to move plants into their planting positions
- propagation compost could be your own or a commercial mix
- after emergence, drop air temperature to 24°C until plants are established. After that night temperature can be lowered to 21°C. Minimum day temperature is 23-25°C, venting at 27°C.

As an alternative to tray sowing, it is possible to sow directly into peat blocks. Growers use home-made blocking compost or commercial mixes. The two biggest problems with sowing in peat blocks are watering and temperature. Blocks should be watered as frequently as necessary to prevent drying out at any stage and they should be handled carefully at all times to prevent damage. It is preferable to use chitted seed for sowing in blocks. For hydroponic culture use 15 cm rockwool blocks which can be directly seeded or into which seedlings can be transplanted. The blocks should not be allowed to dry out at any stage. A complete fertilizer 1 1 N K fertilizer with all trace elements should be started when true leaves are emerging.

Early Culture

The peat-based composts should always be kept moist and never allowed to dry, because they are difficult to rewet and often root damage can result. Liquid feeding should start when the fourth or fifth leaf has emerged from the head and can be applied continuously onward. **IF THE COMPOST DRIES AT ANY TIME A CLEAR WATERING SHOULD BE GIVEN TO WET UP THE SUBSTRATE BEFORE REVERTING TO LIQUID FEED.** This will reduce the risk of root scorch.

Apply 10-52-10 or 9-45-15 at a rate of 100 g L of stock solution at 1:100 injector ratio. Apply once a week for three weeks. In addition mix equal parts of potassium nitrate and calcium nitrate and use 100 g L of stock at 1:100 ratio. This fertilizer can be applied as a constant feed.

Space the plants as they grow. Don't allow them to tip over. If the need arises stake them properly.

GROWING SYSTEMS

Root diseases and nematodes have necessitated the development of isolated growing systems. Many growers in Alberta use peat bags, nursery containers with 1:1:1 soil:peat:vermiculite mix and various hydroponic systems. Rockwool culture is commercially practised in Europe. At the Alberta Horticultural Research Center, Brooks, work has been done on the use of rockwool.

Soil Culture

A number of different soil-based systems are used for cucumber production. They are: direct planting into soil; planting on strawbales with a top cap of soil; or using 50 per cent soil with peat moss and vermiculite in containers. Any system which uses the soil requires annual sterilization either by steaming or by the application of chemicals. Please refer to the general soil section for management. The nutritional status of the soil should be determined before planting. Base fertilizer applications should be made according to the soil analysis.

Straw Bale Culture

Refer to page 6 for details.

Soil:Peat:Vermiculite
Cucumbers can be successfully grown in a homemade blend of 50% soil 25% coarse peat moss and 25% coarse vermiculite. Use 25 litre plastic bags or containers with drainage holes 2.5 cm above the base. The mix should be sterilized properly. It is advisable to put gravel or straw at the base of the pot to improve drainage.

Peat
Cucumbers are grown in commercially prepared peat modules. Two types of modules are available. One type is made from a woven type of plastic and the other is from 2 mil plastic. These bags demand different water management, because it is easy to leach nutrients from the woven type. Each bag usually contains about 50 litres of compost and is suitable for growing two cucumber plants. The composition of a mix is given on page 7. Research at the Alberta Horticultural Research Center, Brooks, has shown that peat modules can be used for two years.

Rockwool
Rockwool is an inert growing medium which is compressed into slabs, commonly 190 x 30 x 10 cm in size. It has a high water-logging capacity, but also aerates well. It has no nutrient retaining properties, hence continuous liquid feed is necessary. Rockwool as a growing medium for cucumbers produces satisfactory crops, although there is no indication that the production level is any higher than when using soil. Trials at the Alberta Horticultural Research Center are encouraging.

The layout generally consists of a base of styrofoam insulation with a groove on its upper surface into which a root zone warming pipe can be fitted. Rockwool slabs lie on this, wrapped in a white or black plastic sheet. The plastic wrap is slit to allow excess solution to drain away just above ground level. Plants are raised in 10-15 cm plastic wrapped rockwool blocks, which are then simply placed at the appropriate plant density along the row. Bottomless plastic pots appeared satisfactory in the trials at Brooks. Peat pots may develop capillary problems, so they are not recommended at this stage.

A drip irrigation system is necessary with one nozzle for each propagating block and one nozzle in the rockwool slab. Some cucumber cultivars may respond better than others.

Nutrient Film Technique
NFT was developed by Dr. A. Cooper of the Glasshouse Crops Research Institute, Littlehamptom, England. The nutrient solution is contained in a large catchment tank from which it is pumped through a manifold header line situated at the top of the rows of plastic channels. Seedless cucumbers can be grown in NFT. Early yields are usually high but it is difficult to maintain long-season vigor. Fifteen weeks after planting, the roots die and plants generally do not recover.

Sawdust
Sawdust provides an inexpensive, well drained and initially a disease-free environment for root development. Use a moderately fine sawdust as the water distribution through the bags is more uniform. Douglas fir *(Pseudotsuga menziesii)* and Western hemlock *(Tsuga heterophylla)* are the main types of sawdust commonly used, although other kinds of conifer sawdust have been used successfully. Avoid large proportions of western red cedar *(Thuja plicata)* in the sawdust. Prior to using the sawdust, check the conductivity to determine if there has been a salt accumulation. An analysis for manganese is also recommended as this mineral can accumulate in the wood to levels toxic to cucumbers. Moisture does not spread well laterally in pure sawdust. Place a 1-2 cm thick layer of clean, sterilized sand over the top of the sawdust to improve moisture distribution.

White plastic bags (15 cm x 25 cm x 30 cm) are recommended. They contain 10 L of sawdust for one cucumber plant. Bags should have some drain holes. Bags and sawdust are changed yearly with the crop. Other containers can be adapted or plants may be grown in beds. Beds are typically constructed with sides of wood and the bottom of shaped ground for drainage. The bottom is covered in plastic to prevent rooting out by the plants. The beds must contain 10 L of sawdust for each cucumber plant.

Containers can be filled by hand or by using a funnel arrangement on a stand. Electrically driven augers or belted elevators with a foot operated switch work well and give the operator good control of the sawdust flow.

Bags or containers are placed in the greenhouse on drop sheets of plastic. White is preferable as it reflects more light. When establishing a greenhouse for sawdust culture ensure good in-ground drainage.

STANDING OUT
Young plants should always be spaced out so that their leaves do not overlap. Plants should be properly supported with split canes to which they are attached by 5 cm plastic clips. Care must be taken that the plants do not become chilled while they are being moved between the propagation area and the growing house. They should not suffer physical damage. If the plants are not to be allowed to root into the growing medium immediately, they should be stood on plastic strips, discs or hardboard squares. Make sure that they do not stand in a pool of water after watering.

PLANTING

The stage of planting depends on the growing program Early spring crops are planted when they have developed 4-5 true leaves and roots fill the propagating pot. It is important that there should be no delay beyond this stage, because excessive root development within the pot can inhibit rooting out after planting. It will retard establishment into the growing medium. Later crops can be safely planted at an earlier stage, because better growing conditions make it easier to establish a satisfactory balance between vegetative growth and fruit development

To plant into soil or into the capping material over straw, a planting hole should be made a little deeper than the depth of the propagating pot. Make sure the pot sits well down into the bottom of the hole. If the plants have been raised in disposable pots, water the plants and knock them gently out of the pots before planting. Discard any plants with brown roots or a poor root system. Do not handle the plants by the stem. Lightly firm the growing material around the root ball. Plants should be watered in by hose with about half a litre of water per plant. Planting into peat should be carried out in a similar way, except that the root ball or pots should be planted only to half its depth if the peat has already been wetted.

Sawdust bags should be moistened with warmed water prior to planting out. Do not allow bags to dry out until a full root system has developed. This may require hand watering the bags three to four times a day.

Rockwool blocks should be placed on rockwool slabs and fertilizer applications should start immediately.

PLANTING DENSITY

The distance between the rows should take into account the width of the greenhouse, the position of posts, the need for workers to move down the rows and the training system that will be used. If the V-system is used, the minimum average row width is 1.5 m and spacing in the row can vary from 40-50 cm. If the plants are trained vertically, row spacing can be reduced to one metre while the distance between the plants should be increased to 70 to 80 cm. In any case, the plant population should not exceed 1.6 plants per m^2.

ESTABLISHMENT

Early culture after planting should be aimed at encouraging rapid rooting into the growing medium and striking a balance between vegetative and fruit growth. Plants should be kept healthy and free from stress. For the first week or two watering should be carried out carefully. Water should be applied to the root zone whenever drying back starts, but only enough should be given to keep the root ball moist without excessive wetting of the growing mix. Excessive amounts of water will result in too lush vegetative growth and cucumbers will not fill in

The principal aim should be to maintain a high humidity in the air, even if this means limiting ventilation under some conditions. Proper humidity levels are very critical when bags are used for growing Damp the walkways more frequently. Use overhead sprinklers, stopping in time for the plants to dry off before dusk

Young cucumber plants are very susceptible to a number of root rot fungi. *Pythium* infection is common during the establishment period. Avoid cold water shock to the plants Follow the recommendations to control damping off

TEMPERATURE

The temperature of the growing mix is extremely important for cucumber production. The minimum temperature is 20°C while 22-24°C is generally considered to be the optimum.

Temperature can be used to maintain the balance between fruit production and vegetative growth. By lowering the night temperature, vegetative growth and strong flower development are promoted. Conversely, by raising the night temperature, rapid fruit development will result. The following program is suggested:

First four weeks after planting	19-20°C nights, 23-24°C days
Until two weeks after picking starts	18-19°C nights, 23-24°C days
Until the end of the crop	17-18°C nights, 23-24°C days

Although the program proposed above will give satisfactory crops, a number of minor modifications may be made by the experienced grower to suit particular circumstances. Lower than recommended temperatures, particularly when the reduction is sudden, can cause malformation of developing fruit, and if the low temperature persists there may also be pale surface scar tissue formed on the fruit.

CARBON DIOXIDE ENRICHMENT

Carbon dioxide enrichment is of economic value for cucumbers, especially from January to May. The level of enrichment should in general be limited to 1000 ppm, particularly during propagation. Mature crops can tolerate between 1500-2000 ppm. Enough air should be available to burn natural gas to generate carbon dioxide. This can be achieved by opening the ridge vents 4-6 cm. Modern carbon dioxide generators have proper exhaust and fresh air intake systems. Carbon dioxide should also be used in summer before ventilation by exhaust fans starts.

IRRIGATION

An adequate supply of water of suitable quality is necessary for cucumbers. Water with high levels of sodium or chloride (more than 100 ppm), can cause problems, particularly on crops grown on soilless media. Hard water increases the risk of blockages in the irrigation system, especially if phosphates are included in the liquid feeding programs. Water quality is more critical for crops in rockwool or NFT. Please refer to water quality on page 9 for special management practices.

Cucumbers require a good deal of water. During peak consumption in the summer months the crop will require up to 30-40 L/m^2 per week. The amount of water used is very closely linked with the total amount of light radiation. In Europe solarimeters or evaporimeters are commonly used to determine water use.

Many application methods are used, depending on the growing system. Crops grown in soil are watered by 2-3 cm diameter PVC or black plastic pipe with 360° nozzles. These nozzles are usually 0.5-0.8 m apart. The pipe runs in the middle of the growing bed. Watering frequency varies from two or three times weekly from December to March to two or three times daily from April to September. If plants are watered less frequently make sure that the fertilizer solution is more concentrated.

Trickle or drip systems are necessary for crops in peat, sawdust bags or rockwool slabs. Uniform application is important, otherwise some areas will be dry while others will be waterlogged. With crops grown in peat or sawdust bags there is a much smaller reserve of water available and applications may need to be made up to eight times a day. Once the peat or sawdust bags are properly wetted, they should be slit or have holes punched in them to allow drainage of excess water. Slits are made about 2.5 cm above the floor. The volume below the slits acts as a reservoir which reduces the risk of the peat drying back between waterings. The same thing can be done in the case of rockwool systems, which also have a low water capacity, and so need frequent applications of small volumes of water.

FEEDING

Soil

Cucumbers must have a proper balance of nutrients continuously to produce a full crop of high quality fruit. Feeding programs should be developed which maintain low soluble salt levels but maintain soil nutrient levels in the range shown in the Table 1.

Soils differ widely in the amounts of nutrient reserves that they can supply to plants. A highly fertile soil probably has enough of all the nutrients for the production of one good crop, but continued cropping will deplete these amounts. Light sandy soils have very limited reserves. The amounts present in a soil can be determined from a soil test.

It is, therefore, necessary to use a large amount of fertilizer for good crop production, especially in light sandy soils. Depending upon the amount of fertilizer or manure premixed, fertilizer application should start two to three weeks after transplanting. If manure has been used, enough potassium will be available to last until the first stem flush of cucumbers. Levels of nitrate nitrogen and ammonium nitrogen should be regularly measured, especially when the growing medium has been pasteurized by steaming, or chemicals like Vorlex or Basamid have been used.

High analysis soluble fertilizers can be metered into the irrigation water.

A schedule for the weekly application of fertilizers is shown in the following table. The schedule is based upon experience with growers in Alberta and at the Alberta Horticultural Research Center. To estimate the fertilizer needs of the crop, growth should be carefully watched and the tissue and leaf test should be made regularly. No formula can take the place of good judgment. The schedule should be used only as a guide and should be adjusted to suit the fertility level and the progress of the crop in each greenhouse. Omit the feeding completely if cloudy weather prevails for a week. Reduce the feeding by one half if cloudy weather prevails for three to four days.

Guide to weekly application of fertilizer for spring crop of seedless or seeded cucumbers grown on soil.

	Recommended Fertilizer — kg/100 m²						
Week after transplanting	10-52-17 or 11-48-0 or 12-53-0	13-0-44 potassium nitrate	15.5-0-0 calcium nitrate	34-0-0 ammonium nitrate	21-0-0 ammonium sulfate	Epsom salts magnesium sulfate	Trace elements
1	1.0						
2	1.0						
3	1.0						
4		0.5	0.5			1.0	
5		0.5	0.5				
6		1.0	1.0				
7		1.0	1.0				
8		1.0	1.0	0.5		1.0	0.1
9		1.0	1.0	0.5			
10	1.0	1.0	1.0	0.5			
11		1.0	1.0	0.5			
12		1.0	1.0	0.5		1.0	
13		1.0	1.0	0.5			
14	1.0	1.0	1.0	0.5			
15		1.0		0.5	0.5		
16		1.0		0.5	0.5	1.0	
17		1.0	0.5	0.5			
18		1.0		0.5	0.5	1.0	
19	1.0	1.0	0.5	0.5			
20		1.0		0.5	0.5		
21		1.0	0.5	0.5			
22		1.0		0.5	0.5	1.0	
23		1.5	0.5	0.5			
24	1.0	1.5		0.5	0.5		
25		1.5	0.5	0.5			
26		1.5		0.5	0.5		
27		1.5	1.0	0.5			
28	1.0	1.5		0.5	0.5		
29		1.5	1.0	0.5			
30		1.5		0.5	0.5		
31		1.5	1.0	0.5			
32		1.5		0.5			

When a crop is planted in July-August as a fall crop, start feeding from week 24 onward. If water contains 100 ppm or more of calcium, then reduce calcium nitrate (15.5-0-0) by half and increase 34-0-0 by 0.2 kg/100 m^2. For high fertility soil, apply fertilizer at half the recommended rate until around the thirteenth week, then resume the recommended rate.

Liquid Feeding of Soil Grown Crops

Several methods of liquid feed application are available commercially, any of which is suitable provided it gives a known and consistent rate of dilution. Two or three head fertilizer injectors with dilution ratios of 1:100 or 1:200 are commonly used. One head is used for calcium nitrate only and second head is used for phosphate and sulfate containing fertilizers.

The rates listed below are based on grams of fertilizer/100 L of water. If a 1:100 injector is used then dissolve the fertilizer amount in one litre of water. Double the rates if injector ratio is 1:200.

Immediately after planting apply monoammonium phosphate or a commercial plant starter 100 g/100 L.

Apply about one litre per plant, two times a week depending on weather conditions. Continue starter feed for 3-4 weeks.

Main feed, 4 weeks after planting

Stock Barrel A:	Potassium nitrate	100 g/100 L
	Monoammonium phosphate	50 g
	Magnesium sulfate	50 g
	*Chelated trace elements	3 g
Stock Barrel B:	Calcium nitrate	75 g

use as constant feed.

8 weeks after planting

As above, but increase 13-0-44 to 150 g and calcium nitrate to 100 g. Provide additional 3 g/100 L of iron chelate if iron deficiency appears. Commercially available formulations are 20-5-30 or 20-10-30. They can be used at a rate of 100-150 g/100 L, instead of potassium nitrate and monoammonium phosphate. Use calcium nitrate as suggested above. If new growth is poor, add ammonium nitrate at a rate of 50 g/100 L. If magnesium deficiency appears as interveinal chlorosis on lower leaves, increase magnesium sulfate to 100 g. Modify the feeding program according to the soil test results, leaf analysis and condition of the crop.

Peat Systems

The reserve of nutrients in peat or peat based media is less than in soil, and the levels can change rapidly. Therefore, regular and accurate liquid feeding is required. Peat should be analyzed regularly throughout the season and adjustments in the fertilizer program made accordingly.

Commercial peat bags contain different amounts of nutrients, depending upon the manufacturer. It is advisable to use proprietary fertilizer formulations. The following fertilizer program used at the Alberta Horticultural Research Center, Brooks, gave satisfactory results.

Immediately after planting into peat modules, up to 4 weeks

Plant starter fertilizer

10-45-15 or 10-52-10 or 10-52-17 — 80 g/100 L

\+ potassium nitrate — 100 g/100 L

The growing mix is dry in the beginning. Moisten the bags with the above mentioned fertilizer solution once before planting at a rate of 600-800 mL/plant. Immediately after transplanting into the peat modules apply another 600-800 mL of plant starter fertilizer solution. Thereafter apply 4-5 L/plant/week, approximately 2-3 times/week depending on weather conditions. The plants should be kept on the dry side. Do not soak the peat modules or there will be too much vegetative growth and a poor fruit set, especially in dull weather.

Main feed, 4 weeks after planting

When fruit is setting well, increase liquid feed to 2-3 L per plant per day. Run the plants on the wet side.

Potassium nitrate	100 g/100 L
Monoammonium phosphate	30 g
Magnesium sulfate	50 g
*Chelated trace elements	5 g
Iron Chelate	2 g
Calcium nitrate	50 g

8 weeks after planting

Increase potassium nitrate to 150 g/100 L
and calcium nitrate to 75 g

Take leaf analyses at regular intervals and make adjustments accordingly.

Extra nitrogen can be made available from ammonium nitrate or urea between April 1 and October 30 when vegetative growth is desirable.

Rockwool and NFT

In the case of rockwool systems or nutrient film growing there is no reserve at all of nutrients in the rooting area. The supply of nutrients has to be very accurate and constantly monitored. The following fertilizer program has been successfully used at the Alberta Horticultural Research Center, Brooks.

Rockwool: up to 4 weeks from planting

Potassium nitrate	50 g/100 L
Monoammonium phosphate	100 g/100 L
Magnesium sulfate	50 g
Chelated trace elements	6 g
Calcium nitrate	50 g/100 L

after 4 weeks and up to 8 weeks

Potassium nitrate	100 g/100 L
Monoammonium phosphate	40 g
Magnesium sulfate	50 g
Chelated trace elements	6 g
Calcium nitrate	65 g/100 L

after 8 weeks

Potassium nitrate	150 g 100 L
Monoammonium phosphate	40 g
Magnesium sulfate	50 g
Chelated trace elements	6 g
Iron chelate	2 g
Calcium nitrate	100 g 100 L

NFT

Ammonium and urea type nitrogen should not be used in NFT systems

[illegible]	[illegible]
Monopotassium phosphate	20 g
Potassium sulfate	50 g
Magnesium sulfate	50 g
Chelated trace elements	8 g
Iron Chelate	2 g
Phosphoric acid 75%	10 ml
Calcium nitrate	100 g 100 L

Use half strength for the first two weeks

Sawdust

Fertilizer:		Concentration (ppm)	for 1000 L
A. Potassium sulfate (0-0-50)		210 K	508 g
Magnesium sulfate		50 Mg	500 g
Diammonium phosphate (21-53-0)		36 P	[illegible]
		33 N	
Calcium nitrate (15.5-0-0)		135 N	875 g
		148 Ca	
or			
B. Potassium sulfate (0-0-50)		80 K	193 g
Potassium nitrate (13-0-44)		30 N	230 g
		84 K	
Magnesium sulfate		25 Mg	250 g
Monopotassium phosphate (0-53-34)		36 P	160 g
		44 K	
Calcium nitrate (15.5-0-0)		140 N	900 g
Minor Elements			
Iron chelate (10% Fe)	Fe	3.0	30 g
Manganese sulphate (28% Mn)	Mn	0.6	2.07 g
Boron (20.5% B)	B	0.7	3.4 g
Zinc sulfate (36% Zn)	Zn	0.1	276 mg
Copper sulfate (25% Cu)	Cu	.03	120 mg
Molybdenum (54% Mo)	Mo	.05	92 mg

After planting out, place drippers on the bags at the edge of the rootball. Allow three drippers per plant if no sand is used on the bags. Do not place a dripper near the stem as it may encourage the development of crown rot. Full strength fertilizer solution can be given to the plants.

Time fertilizer applications at regular intervals during the day such as hourly or half hourly if using a time clock system. Allow 10-20 per cent leaching to ensure no soluble salt accumulation. Start with 800-1000 mL per day and adjust feeding volumes upwards as sunlight and size of plants increase. Rates given to mature plants will be 4-7 L per day. Keep the sawdust moist but not saturated. Feeding once or twice during the night reduces plant stress and has been shown to be beneficial. Ensure that the feeding solution temperature is 20°C (minimum) when applied.

Formula A may require the addition of sulfuric or phosphoric acid to lower the pH of the fertilizer solution. A milky precipitate after tank mixing indicates the need for pH adjustment.

If the water is particularly alkaline, phosphoric acid may be used as the phosphorus source. Contact the greenhouse crops specialist for further information on pH adjustment.

Commercially available microelement mixes can be used satisfactorily. Adjustments must be made in the above feeding program depending on water quality. For example, if calcium levels are greater than 100 ppm in the water supply, calcium nitrate has to be reduced. Additional nitrogen must be made available through the use of ammonium nitrate. Contact the greenhouse crops specialist at the Alberta Horticultural Research Center, Brooks, for further recommendations.

TRAINING THE PLANTS

The plants can be trained to a V-cordon or to a vertical cordon system. The largest amount of available light is intercepted when the V-system is practised. Also, fewer rows are required because of the greater distance between rows and, if the crop is grown on straw bales or in heated soil, a saving on labor and materials is obtained.

The V-system can be described as follows: Two crop wires are placed 2.2 to 2.5 m above ground over each row of plants, the wires spaced so that they are 60 to 80 cm apart. The strings for the plants are then tied alternately to the overhead wires so that the plants are inclined away from the row on each side. The plants will then be growing in a V-arrangement, down the row, allowing light to fall more uniformly on the plants and allowing fruit to hang away from the main stem.

Support cucumber plants by tying them to strings that are suspended from a horizontal wire. Use heavy sisal or polyethylene twine for the supporting string. Loosely attach the supporting string around the main stem at the base of the plant with a nonslip knot. Do this a week or so after transplanting when vertical growth is beginning. As the plants grow, loosely wind the main stems around the string, or attach the stems to it with special plastic clips. The plastic clips should be tied at the base of the leaf. Do this frequently enough to prevent any sagging or stem bending. If the mainstem gets broken, then encourage a side shoot to develop and train it as the main stem.

PRUNING

You can use various pruning and trimming systems to avoid excessive growth and maintain fruit production. On gynoecious types, female flowers and lateral branches are produced in every leaf axil throughout the plant. The goal of pruning is to leave the maximum amount of leaf surface and developing fruit that the plant can support, but not so much that it interferes with air circulation or seriously reduces the supply of light to lower leaves. A basic practice in all pruning systems is to remove all lateral branches and main stem fruit from the first five to seven nodes. If not removed, the fruit on these lower nodes will touch the bed surface during the development, becoming second-grade fruit because of curvature, or unmarketable because of decay at the tip. Leaving fruit at the lower nodes will result in fruit aborting at the upper nodes.

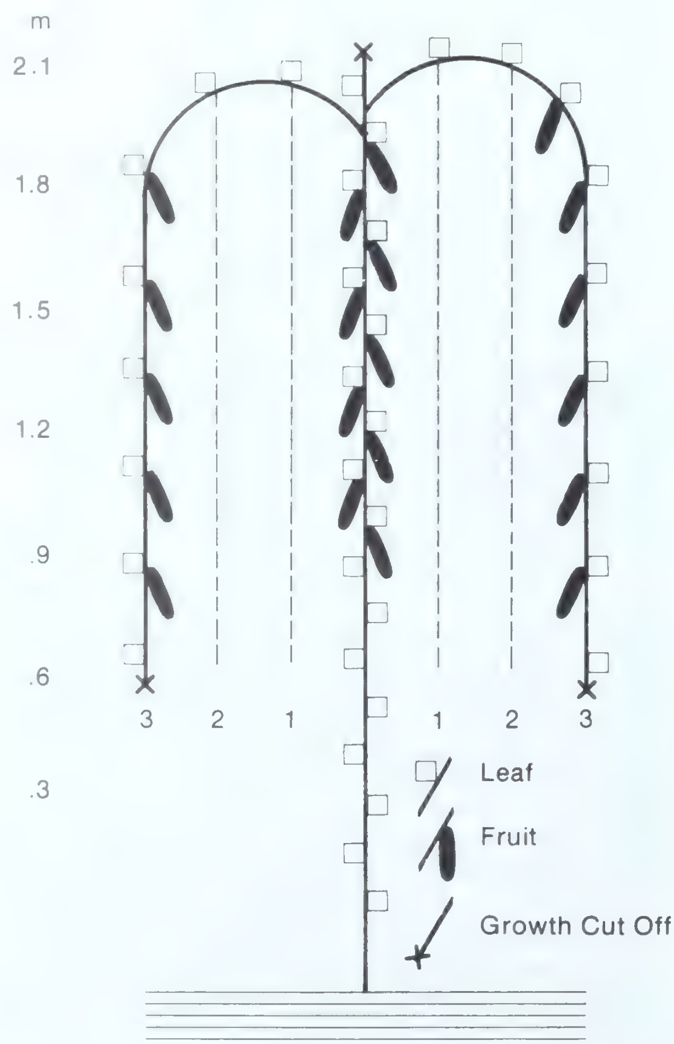
Renewable Umbrella System

This is one of the more commonly practised training systems. It is simple and not labor intensive. Each plant must be considered individually, on the basis of its vegetative vigor and fruit load. A correct balance between these two factors must be maintained.

If too many fruits are allowed to form at any one time, a large proportion will abort because the plant may not have sufficient food reserves to develop them. If a heavy load of fruit sets, many fruits will be malformed, curved, short or poorly colored, and therefore unmarketable. Remove them at an early stage. Multiple fruits in one axil should be reduced to one.

Too much vegetative growth is detrimental, because leaves may develop at the expense of fruit. A dense canopy of leaves will shade fruits from sunlight, causing them to be pale in color.

Figure 5.



1. The main stem should be stopped at one leaf above the wire. Pinch out the growing point at that level. Tie a small loop of string around the wire and below the top leaf, so that the plant will not slide down the main string.
2. Do not allow fruits to develop on the main stem up to about 130 cm.
3. Before they grow out, remove all laterals in the leaf axils on the main stem, except two at the top.
4. The top two laterals should be trained over the wire to hang down on either side of the main stem. Allow these to grow to two-thirds of the way down the main stem.
5. All secondary laterals should be removed except two at the top.
6. While the fruit on the first laterals is maturing, the second laterals should be allowed to grow out and downward.
7. When the fruits on the first laterals have been harvested, those laterals should be removed back to a strong shoot, allowing the second laterals to take over.
8. Repeating steps (5), (6) and (7) in this renewal system will maintain productivity of plants.
9. Remove old large leaves which have become unproductive. Snap the leaves off close to the main stem. Do not leave long stubs hanging on.

Good quality fruit will not develop unless there is a continuing production of lateral shoots. It may be necessary to resort to major pruning to stimulate growth. In this case, it is better and less costly to cut out whole unproductive laterals than to snip back the tops of several weak ones.

FRUIT HARVEST

Cucumbers are harvested when they are uniform in diameter and meet the minimum grade standard for Canada No. 1. They are cut from the plant two to three times a week, leaving a small stalk attached to the fruit.

GRADING AND PACKAGING

After harvesting, the cucumbers are graded as either Canada No. 1 or No. 2 based on size, shape, color, maturity, freedom from disease, injury, defects and damage; cleanliness and size. Canada No. 1 cucumbers must be a minimum of 30 cm in length, and if harvested from October 1 to March 31, 38 mm in diameter, and if harvested from April 1 to September 30, 42 mm in diameter.

Cucumbers are shrink-wrapped to increase shelf life and are packaged in twelves in cardboard boxes. Cucumbers should be handled carefully as they bruise easily.

STORAGE

Cucumbers can be stored at 10 to 12 C for approximately a week, although the shorter the time in storage, the longer the product will last for the consumer. Temperatures below and above these will cause softening and fruit deterioration. Cucumbers also will deteriorate rapidly in the presence of ethylene and should be kept apart from ethylene-producing products such as tomatoes, melons, apples, peaches and other fruit.

SHELF LIFE

The shelf life of cucumbers depends on the length of time in storage, the storage conditions, and the color and skin type of the fruit. Dark green cultivars last longer than lighter green cultivars. Ribbed fruit lasts longer than smooth-skinned because it is less easily damaged during handling.

DISEASE CONTROL — GENERAL

INTRODUCTION

The alert greenhouse grower who can recognize plant diseases and knows how to deal with them will grow a more profitable crop. Some diseases can be prevented if they are recognized early, or their impact can be reduced if appropriate control recommendations are followed. To understand the reasons for control recommendations, it helps to know about the diseases and the agents that cause them.

DEFINITION OF PLANT DISEASE

Disease means a disturbance in function accompanied by the appearance of symptoms. The reaction of a plant to the cause of the disturbance produces the various symptoms by which we recognize disease. Whether the disease is important depends on how seriously it affects the yield and quality of the product.

CAUSES OF PLANT DISEASES

Diseases are caused either by unfavorable conditions in the environment (noninfectious disease) or by microorganisms (infectious disease).

Some common causes of noninfectious diseases in greenhouse crops are:

1. Low temperature (e.g., chilling injury).
2. Chemical injury (e.g., improper application of a pesticide).
3. Lack of nutrients (e.g., nitrogen deficiency).
4. Excess water (e.g., "wet feet" condition from lack of oxygen around the roots).

Four types of microorganisms commonly cause infectious diseases on greenhouse crops.

Bacteria: The simplest living organisms known to man are bacteria. Some are so small that 5,000 of them laid end to end would not measure more than one centimetre.

Many bacteria are beneficial to man. They feed on dead organic matter such as leaves on the ground and make more nutrients available to plants. Other species of bacteria are pathogenic and can enter plants through natural openings or wounds. Bacteria can be brought to plants by insects, flowing or splashing water and workers' hands. Some bacteria are carried in or on the seed.

Fungi: Fungi or molds are very common organisms. Fungi cannot make their own food, and must feed on plants and organic matter. Although there are thousands of different kinds of fungi, the few that attack living plants concern us most.

For the most part, fungi reproduce by spores, very tiny bodies that look and behave much like seeds. Some fungi are capable of producing millions of spores which can be spread by air currents, water, insects and other means. Under favorable conditions, a spore landing on a susceptible plant can produce a new infection centre. Often, the plant surface must be injured before the fungus can enter. Injury of plant parts is very common, and can be caused by insect bites, bruises, foliage rubbing together, pruning, etc. Under unfavorable conditions, some fungi produce special spores or other resistant structures that will allow the fungi to survive until more favorable conditions for infection exist. Certain fungi grow best at relatively high temperatures and low humidities (e.g., powdery mildew) while others prefer a cool, moist atmosphere (e.g., Botrytis grey mold).

Viruses: These tiny particles are so small that they cannot be seen through an ordinary light microscope. However they are responsible for some of the most serious diseases in plants.

Viruses produce a wide range of symptoms on plants. They are grouped into two general types: mottling, spotting or striping of the leaves; and yellowing, leaf curling or dwarfing of the plant. Very often it is difficult to tell if a plant has a virus disease because no distinct symptoms are produced. Plant tissues cannot be penetrated directly by viruses and there must be a wound on the plant through which infection can take place. Aphids, leafhoppers and other insects with sucking mouthparts are the most important virus carriers. Tobacco mosaic virus (TMV) can be introduced into a greenhouse on contaminated cigarette tobacco and tomato and related plants can become infected. Viruses may also be carried in seed, tubers or bulbs.

Nematodes: Nematodes are small thread-like worms, usually from 0.5 to 1 mm long. Not all nematodes are harmful. Some feed on decaying organic matter and help build fertile soil. Plant parasitic nematodes may be found in the stems, petioles, leaves or roots. Those that feed on the roots cause the greatest amount of damage. Most plant parasitic nematodes possess a miniature hollow spear called a stylet. This stylet is used to puncture the cells of the root after which the nematode sucks out the contents of the cells. Some nematodes actually enter the root and spend most of their lives there. Others remain outside the root. Even though only a few nematodes may be feeding on a single root and causing only slight damage the wounds allow fungi or bacteria to enter and kill or seriously damage the plant. Some nematodes form knots or galls on the roots of the plants. These structures slow the intake of water and minerals from the soil and cause the plant to be stunted.

DIAGNOSING PLANT DISEASES

The first step in combating a plant disease is to recognize that a problem exists. Next, one must identify the causal agent and determine whether it is noninfectious or infectious. This procedure is the art and science of diagnosis. The following are some important points to remember in diagnosing diseases of greenhouse crops:

a) An accurate diagnosis is *essential* before timely and appropriate control measures can be applied.

b) Examine all of the facts at hand. Like a detective, look for clues in cultural practices, unusual growing conditions, etc. Don't always assume that an infectious agent is the cause of the disease.

c) Know the crop. Many disease problems, especially noninfectious ones, can be prevented if one has a sound knowledge of the growth characteristics, nutritional requirements and optimal environmental conditions for good growth.

d) Learn to recognize the signs of insect and mite infestations. They can be easily confused with symptoms of certain diseases.

e) Close observation of symptoms with the naked eye should indicate the general type of disease, e.g., leaf spot, wilt, root rot, etc. Closer examination of the surfaces of spots, cankers, etc., with a magnifying glass will often reveal the presence of spore-bearing bodies of fungi, bacterial exudates, insects or mites, etc. Diseased areas showing no evidence of surface growths could be young infections which may later develop structures or they may be the result of conditions causing noninfectious diseases.

f) Don't be afraid to consult a specialist for help. Alberta has regional plant diagnostic laboratories at Brooks, Olds, Vegreville and Fairview. Each laboratory is staffed with plant pathologists and entomologists. The addresses are given on page 41.

DISEASE CONTROL RECOMMENDATIONS

The recommendations which follow include cultural, biological and chemical control measures as outlined in the most recent issue of the *Guidelines for Plant Disease Control in Western Canada* prepared by the Western Committee on Plant Disease Control. Before using any chemical, carefully read the manufacturer's instructions on the label. All pesticide products registered for use in Canada are licensed by Agriculture Canada. No disease control chemical should be used on any crop for which it is not registered. Such use may pose a threat to consumers of the treated produce and can result in seizure and destruction of the crop by federal inspectors.

Unless otherwise specified, all materials should be applied so as to obtain thorough coverage of the foliage. Applications can be repeated every 7-14 days as long as there is a threat of disease spread.

NOTE: Over a period of time, disease organisms may become resistant or immune to certain pesticides. Therefore, it is advisable to make applications of alternate recommended chemicals where more than one is registered for use against a specific pathogen.

PEST CONTROL

CODE FOR THE SAFE HANDLING AND USE OF PESTICIDES

1. Always read the label before opening the container.
2. Use at recommended rates. Apply as directed.
3. Wear clean protective clothing as outlined on the label.
4. Do not inhale fumes, spray or dusts. Avoid skin contact. Wash immediately after accidental contact.
5. If pesticides are spilled on clothes, change immediately.
6. Do not eat, smoke or drink when mixing or applying or until after wash-up.
7. Follow "days to harvest" on label and in this production guide.
8. Cover food and water containers when treating around livestock or pet areas. Do not contaminate water.
9. If any illness or abnormal condition occurs during or shortly after pesticide use, call a doctor immediately.
10. Wash equipment thoroughly after each pesticide application.
11. Shower or bath thoroughly after working with pesticides.
12. Use separate equipment for applying hormone type herbicides in order to avoid accidental injury to susceptible plants.
13. Always store pesticides in original containers and keep storage locked.
14. Keep ALL pesticides out of reach of children and animals.
15. Take precautions to reduce hazardous pesticide drift.

DISEASES

Basal Stem Rot and Root Rot

Before planting sterilize the soil with steam or use a soil fumigant (see Soil Sterilization, page 7). Transplant into a well prepared, warm soil (temperature 20 C). Apply a ferbam spray (190-200 g 100 L) and avoid cold water shock as described on page 24 for late damping off.

Black Root Rot

It first appears as a wilting of apparently normal plants during bright sunny weather. Examination of roots of wilted plants reveals that most have disintegrated, and those remaining exhibit tiny black pepper-like dots on the outside and black streaks on the inside. Infected plants seldom die outright but production may be reduced by 50 per cent or more. This disease may occur in sawdust culture.

Control: Avoid introducing the disease by strict sanitation procedures, including footbaths or overshoes for visitors. Use of new sawdust will usually avoid problems. When using soil or old sawdust fumigate or steam as for Fusarium root rot and wilt OR rotate with tomatoes OR graft on resistant *Curcurbita ficifolia* rootstock.

Ensure that soil temperatures are adequate (20°C) before planting. Affected plants can often be saved by mounding the base of the stems with a clean soil-peat mixture, so that new roots are formed. The mound should cover the area of the first leaf scar on the stem.

Cucumber Mosaic Virus

This disease is characterized by irregular patches of yellow on the leaves, especially young ones. These symptoms sometimes disappear at temperatures over 27°C and as infected plants age. Severe stunting of the top growth and undersized, malformed fruits result from heavy infection by some strains of the cucumber mosaic virus (CMV). Most European seedless cucumbers are highly susceptible to CMV.

Control: Plant disease-free seed. Avoid handling infected plants before healthy ones. Disinfect cutting tools and wash hands thoroughly after handling infected plants. Control insects, especially aphids.

Grey Mold

Grey mold is caused by the fungus *Botrytis cinerea*. Characteristic symptoms are tan-colored lesions with or without masses of grey spores. Young fruits, blossoms and pruning wounds are the most common sites of attack. Top growth above stem infections may ultimately die. Grey mold can attack cucumber plants at any stage of their development and is especially serious in greenhouses with poor air circulation and high humidity. Soft, succulent growth produced by excessive application of nitrogen fertilizer is particulary susceptible to grey mold.

Control: Maintain free air circulation around plants and ventilate freely to reduce humidity. Removing lower leaves will assist air movement. Avoid overcrowding and overfertilizing plants. Pull all weak, dead and severely infected plants and remove all prunings and crop debris from the greenhouse. When pruning, break leaves off close to the stem. Spray stems with a protective fungicide spray soon after pruning or cover the wounds with a thin fungicide paste. Stem infections can sometimes be arrested by scraping them down to healthy tissue and then applying a fungicide paste. The following fungicides are effective against grey mold:

1. Dyrene 50% WP at 200 g/100 L. Do not apply within 1 day of harvest.
2. Ferbam 76% at 200 g or Ferbam 95% WP at 150 g/100 L. Do not apply within 1 day of harvest.
3. Benlate 75 g + Manzate 200, 200 g/100 L. Do not apply within 5 days of harvest.
4. Rovral 50% WP at 100 g/100 L. Do not apply within two days of harvest.

Gummy Stem Blight

The main symptom of this disease is the presence of a gummy, amber-colored ooze, especially at the stem base, followed by wilting and death of the plant. Symptoms usually appear within six weeks after transplanting. Infected areas eventually form dozens of small black fruiting bodies of the causal fungus *(Mycosphaerella citrullina)*. Fruits and leaves may also become infected and exhibit similar symptoms.

Control: Plant disease-free seed or treat the seed with captan or thiram. Maintain good ventilation to reduce humidity. Remove dead and dying plants. Once transplanted cucumbers are established, spray lower stems with one of the following fungicides:

1. Dyrene 50% at 200 g/100 L. Do not apply within 1 day of harvest.
2. Maneb 80% WP at 150 g/100 L. Do not apply within 5 days of harvest.
3. Benlate 50% WP at 50-75 g/100 L in a tank mix with 200-300 g of Dithane M-45 80% WP or Manzate 200, 80% WP. Do not apply within 5 days of harvest.
4. Rovral 50% WP at 100 g/100 L. Do not apply within 2 days of harvest.

High Salts

Plants growing in soils with high levels of soluble salts lack vigorous growth, have small blossoms and scorched or mottled leaves, and generally fail to respond to fertilizer application. A soil analysis should be used to determine salt levels. To correct high salinity, leach with water and use fertilizers that do not contribute to the rapid build up of salts (see Fertilizer Section). Avoid using water containing high salt concentration.

Late Damping Off

Use only vigorous transplants that show no sign of disease. Grow seedlings in containers which can be directly transplanted, e.g., peat pots, bottomless plastic pots or rockwool blocks. Make sure the temperature of soil, peat bags or sawdust is 20-21°C. Avoid cold water shock to young plants by preheating the irrigation water to 21°C. Immediately after transplanting, spray the base of the plants with Ferbam 76% WP 200 g/100 L of water.

Post-Harvest Breakdown

Under certain conditions seedless cucumbers will deteriorate very quickly after harvest. Several diseases may be involved, including gummy stem blight and scab, especially at the stem end after picking. The breakdown is most frequently seen when several unseasonably cool nights alternate with hot, sunny days in late summer months. It also occurs when storage periods are prolonged after picking, especially at improper temperatures and in poorly ventilated areas. There is no one method of preventing this condition, but especially in summer when you have hot sunny days and below normal temperatures at night take care to:

1. prevent disease outbreaks
2. avoid water condensation on the cucumbers, i.e., "sweating" by providing a little heat at night
3. avoid overloading, which weakens the plants and causes unhealthy cucumbers that lack turgidity
4. harvest cucumbers with a sharp knife, leaving a 5 mm stem on each fruit
5. avoid tearing, fruit bruises, cuts and abrasions
6. maintain the temperature for marketing and storing at 10-15°C and ideally at 12°C. The relative humidity of the storage area should be between 85 and 95%.
7. avoid accumulation of ethylene gas in the storage areas by keeping cucumbers away from apples and other fruits and by adequate ventilation.

Powdery Mildew

The first symptom of this disease is small patches of white powdery growth on the leaves. These spots can quickly spread to cover the whole leaf. Severely affected leaves eventually turn yellow, become brown, and shrivel. Stems and petioles may also become infected, but fruits are rarely attacked. Tiny, spherical brownish-black resting bodies of the causal fungus *(Erysiphe cichoracearum)* may appear on infected leaves as they begin to die. Spidermites often seem to build up faster on plants infected with powdery mildew.

Control: Raise humidity, providing grey mold and other foliage diseases are not prevalent. Practise good sanitation. At the first sign of the diseases, apply fungicide sprays, such as one of the following:

1. Karathane WD 19.5% WP at 30-60 g/100 L. Do not apply within 30 days of harvest. Do not apply when temperatures exceed 32°C.
2. Benlate 50% WP at 50-75 g in a tank mix with 200-300 g/100 L of either Dithane M-45 80% WP or Manzate 200 80% WP. Do not apply within five days of harvest. If a serious problem persists grow powdery mildew resistant cultivars.

Pseudo Yellow Virus

A disease not yet diagnosed in Alberta, but recently reported in Ontario. It is spread by the greenhouse whitefly. Symptoms are chlorotic (yellowing) between the veins of older leaves and interveinal yellow spotting on intermediate leaves. Upper foliage may remain unaffected during the early stages. Diseased plants become less productive. There is no known method of control except to control whiteflies. Beets, several species of weeds and lettuce are known to be alternate hosts.

Root Rot and Wilt

Wilt symptoms generally first appear after the stem flush harvest or later. At first, plants may wilt temporarily on sunny days and recover at night, but later they wilt permanently and die. The root systems often look normal, however, internal tissues of the root and stem usually show a slight browning of the vascular (water conducting) tissues. Dead patches of leaf tissue, stunting and poor fruit yield are other symptoms often associated with wilt.

Root rot can attack established plants of any age. Foliage symptoms sometimes resemble those caused by wilt. However the root systems of affected plants show varying degrees of decay and internal discoloration is usually extensive. Root rot and wilt often occur together in the same greenhouse and sometimes even on the same plant. In Alberta, the fungi causing wilt and root rot include species of *Fusarium*, *Verticillium*, *Phythium*, *Rhizoctonia* and *Acremonium*.

Control: Between crops, treat the soil or rooting media with steam or chemical fumigants. Apply captan or thiram dust to the seed before planting. Rotate cucumbers with nonsusceptible crops if practical. Change from soil to a soilless system of growing.

Scab and Leaf Mold

This disease occurs relatively infrequently in Alberta and tends to be restricted to greenhouses with high humidity and large populations of whiteflies. The latter secrete honeydew on which the scab fungus often grows luxuriantly. Early symptoms on the leaves are water-soaked spots which eventually become tan-colored. Old lesions become papery and soon tear away leaving ragged holes in the leaves. Infected spots on fruits often produce a sticky exudate which dries to a brown bead. As the fruits expand, the spots become cavities which, under humid conditions, are lined with velvety, olive-green spores of the causal fungus *(Cladosporium cucumerinum)*.

Control: Reduce humidity by increasing ventilation and raising air temperatures, especially at night. Avoid misting foliage. Practise good sanitation. Spray with Benlate 50% WP at 50-75 g in a tank mix with 200-300 g/100 L of either Dithan M-45 80% or Manzate 200 80% WP. Do not apply within five days of harvest.

Sclerotinia Stem and Fruit Rot

Infection usually begins where there is dead or dying tissue, especially wilting flower blossoms or pruning debris. Affected tissue becomes water-soaked and the causal fungus *(Sclerotinia sclerotiorum)* eventually produces abundant white cottony growth and hard black resting bodies called sclerotia. Stem infections usually lead to death of the plant above the point of infection. If infected fruit escapes detection, the disease can spread rapidly in storage.

Control: Maintain free air circulation around plants and reduce humidity. Benlate sprays for powdery mildew and scab will also help to control sclerotinia.

Tip Burn

Adverse environmental factors such as high air temperature, low humidity and high soluble salts appear to be the main cause of the disorder. Leaf margins appear scorched or bleached out. These tissues are a favorite site of attack for the grey mold fungus. Careful attention to fertilization and temperature control will minimize the occurrence of tip burn.

DIAGNOSING NUTRIENT DISORDERS

WHAT IS A NUTRITIONAL DISORDER?

A nutritional disorder is a malfunction in the physiological processes of a plant caused by either excess or lack of a mineral element or elements and resulting in abnormal growth. External and internal symptoms can be expressed. Distinct symptoms are caused by a deficiency or excess of each essential element which can be used to identify the disorder.

The grouping of essential elements for plant growth is based on their mobility in the plant. Although there is a general gradation of mobility of elements, they are generally classified as either mobile or immobile.

Mobile elements are those which can be retranslocated. They will move from their original site of deposition in older leaves to actively growing regions of the plant such as younger leaves. As a result, the first symptoms will appear on the older leaves on the lower portion of the plant. Examples of mobile elements are: NITROGEN, POTASSIUM, PHOSPHORUS, MAGNESIUM and ZINC.

Immobile elements are those which are not retranslocated to the growing region of the plant when need arises. They remain in the older leaves where they were originally deposited. Deficiency symptoms, therefore, first appear on the upper young leaves of the plant. Immobile elements include: CALCIUM, IRON, BORON, SULFUR, COPPER AND MANGANESE.

ANTAGONISM

Excess of one element affects the uptake of another element. This phenomenon is called antagonism. Some common nutrient element antagonism is as follows:

Element in Excess	Deficiency Caused
Nitrogen	Potassium
Phosphorus	Potassium, Iron
Potassium	Nitrogen, Calcium, Magnesium
Sodium	Potassium, Calcium, Magnesium
Zinc	Iron
Calcium	Potassium, Iron, Boron, Magnesium
Magnesium	Potassium, Calcium, Manganese
Iron	Manganese
Manganese	Iron, Zinc
Copper	Iron

OTHER TIPS FOR DIAGNOSIS

1. Grow an indicator plant along with the regular crop. The susceptibility of different plant species to various nutritional disorders varies greatly. For example, if a crop of tomatoes is being grown, plant a few cucumbers. Cucumbers are very sensitive to boron and calcium deficiency. If such a deficiency occurs the cucumbers will express symptoms from several days to a week before they appear in tomatoes. Tomatoes will show a magnesium deficiency earlier than cucumbers.

2. Weaker plants of the same species will show symptoms before the more vigorous ones.

3. Every possible tactic must be employed to avoid a nutritional disorder in the main crop, since once symptoms are expressed in the crop, some reduction in yield is inevitable.

COMMON TERMINOLOGY USED IN THE DESCRIPTION OF SYMPTOMS ON PLANTS

Localized: Symptoms limited to one area of plant or leaf.

Generalized: Symptoms not limited to one area but spread generally over entire plant or leaf.

Drying (firing): Necrosis — scorched, dry, papery appearance.

Marginal: Chlorosis or necrosis — on margins of leaves initially; usually spread inward as symptom progresses.

Interveinal chlorosis: Chlorosis (yellowing) between veins of leaves only.

Mottling: Irregular spotted surface — blotchy pattern of indistinct light and dark areas; often associated with virus diseases.

Spots: Discolored area with distinct boundaries adjacent to normal tissue.

Color of leaf undersides: Often a particular coloration occurs mostly or entirely on the lower surface of the leaves, e.g., phosphorous deficiency — purple coloration of leaf undersides.

Cupping: Leaf margins or tips may cup or bend upward or downward, e.g., copper deficiency — margins of leaves curl into a tube; potassium deficiency — margins of leaves curl inward.

Checkered (reticulate): Pattern of small veins of leaves remaining green while interveinal tissue yellows — manganese deficiency.

Brittle tissue: Leaves, petioles, stems may lack flexibility, break off easily when touched — calcium or boron deficiency.

Soft tissue: Leaves very soft, easily damaged — nitrogen excess.

Dieback: Leaves or growing points that die rapidly and dry out — boron or calcium deficiencies.

Stunting: Plant shorter than normal.

Spindly: Growth or stem and leaf petioles very thin and succulent.

After the symptoms have been observed closely and described, it should be determined whether the disorder is caused by something other than a nutritional imbalance. The following list of other possible disorders should be checked: insect damage; parasitic diseases; pesticide damage; pollution damage; water stress; light and temperature injury. Pesticide damage may cause burning if greater than recommended dosages are used on the plants. Also, the use of herbicides such as 2,4-D near a greenhouse may cause deformation of plant leaves closely resembling the symptoms of tobacco mosaic virus (TMV). Pollution damage may cause burning or bleaching of leaf tissue or a stippled effect (pinpoint-sized chlorotic spots) on leaves. Water stress, either lack of or excess of, will cause wilting (loss of turgidity) of leaves. Excessive sunlight or temperature may burn and dry leaf tissue, particularly on the margins.

NUTRIENT DISORDERS

Mobile elements (first symptoms on older leaves)

Nitrogen

- stunted growth
- lower leaves — yellowish green
- severe cases — entire plant pale green
- younger leaves stop growing
- fruit — short, thick, light green, spiny

Remedies: 1. Add calcium nitrate or potassium nitrate
2. Use a foliar spray of 0.05 to 0.1 percent solution of urea

Phosphorus

- stunted plants
- severe cases — young leaves small, stiff, dark green
- older leaves and cotyledons — large water-soaked spots including both veins and interveinal areas
- affected leaves fade, spots turn brown and desiccate, shrivel — except for petiole

Remedies: Add phosphorus containing soluble fertilizers, e.g. 20-20-20.

Potassium

- older leaves — discolored yellowish green at margins, later turn brown and dry
- plant growth — stunted, short internodes, small leaves
- later stages — interveinal and marginal chlorosis extends to centre of leaf, also progresses up plant, leaf margins desiccate, extensive necrosis, larger veins remain green

Remedies: 1. Foliar spray of 0.1-0.3% potassium sulfate
2. Increase the amount of potassium nitrate in your fertilizer program.
3. Check for any antagonism.

Magnesium

- older leaves — interveinal chlorosis from leaf margins inward — necrotic spots develop
- small veins — not green
- severe starvation — symptoms progress from older to younger leaves, entire plant yellows, older leaves shrivel and die

Remedies: 1. Check for possible excess of potassium in your soil. It may be the reason for inadequate uptake of magnesium
2. Apply 1% solution of epsom salts to leaves.
3. If magnesium is lacking in your medium, then add magnesium sulfate.

Zinc

- older leaves — interveinal mottling, symptoms progress from older to younger leaves, no necrosis
- internodes — at top of plant stop growing, leading to upper leaves closely spaced, giving bushy appearance

Remedies: 1. Foliar spray with 0.01% solution of zinc sulfate.
2. Add zinc sulfate to your nutrient solution

Immobile elements (first symptoms on younger leaves)

Calcium

- upper leaves — white spots near edges and between veins, marginal interveinal chlorosis progresses inward
- youngest leaves (growing point region) — remain small, edges deeply incised, curl upwards, later shrivel from edges inwards and growing point dies
- growth — stunted, short internodes, especially near apex
- buds — abort, finally plant dies back from apex
- older leaves — curve downward

Remedies: 1. In acute cases use a foliar spray of 0.5% calcium nitrate or 0.4% calcium chloride.
2. Add calcium nitrate to your feeding program.

Sulfur

- upper leaves — remain small, bend downwards, pale green to yellow, margins markedly serrate
- plant growth — restricted
- older leaves — very little yellowing

Remedies: Use sulfur containing fertilizer in feeding programs, e.g., potassium sulfate, magnesium sulfate or ammonium sulfate.

Iron

- young leaves — fine pattern of green veins with yellow interveinal tissue, later chlorosis spreads to veins and entire leaves turn lemon-yellow; some necrosis may develop on margins of leaves
- progression — from top downward

Remedies: 1. In Alberta it is generally due to highly alkaline pH of soil. Reduce pH using sulphuric or phosphoric acid.
2. For quick recovery use a foliar spray of 0.02-0.05% solution of iron chelate once a week for 2-3 weeks.
3. On hydroponic culture add iron chelate to your nutrient solution.

Boron

- apex — growing point plus youngest unexpanded leaves curl up and die
- auxillary shoots — wither and die
- older leaves — cupped upward beginning along margins, stiff, interveinal mottling
- shoot tip — stops growing, leads to stunting

Remedies: 1. Apply a foliar spray of 0.01% solution of borax.
2. Add borax to your nutrient solution.

Copper

- young leaves — remain small
- plant growth — restricted, short internodes, bushy plant
- older leaves — interveinal chlorosis in blotches
- progression — leaves turn dull green to bronze, necrosis, entire leaf withers, chlorosis spreads from older to younger leaves

Remedies: 1. Foliar spray with 0.01% solution of copper sulfate to which 0.5% hydrated lime has been added.
2. Add copper sulfate to your feeding program.

Manganese

- terminal or young leaves — yellowish interveinal mottling, at first even the small veins remain green, giving a reticular green pattern on a yellow background
- progression — later, all except main veins turn yellow with sunken necrotic spots between the veins
- shoots — stunted, new leaves remain small
- older leaves — turn palest and die first

Remedies: 1. Foliar spray of 0.02% solution of manganese sulfate.
2. Add manganese sulfate to your feeding program.

Molybdenum

- older leaves — fade, particularly between veins, later leaves turn pale green, finally yellow and die
- progression — from older leaves up to young leaves, youngest leaves remain green
- plant growth — normal, but flowers are small

Remedies: 1. Foliar spray with 0.07-0.1% solution of ammonium or sodium molybdate.
2. Add sodium or ammonium molybdate to your feeding program.

INSECT, MITES AND OTHER PESTS

INTEGRATED CONTROL

Whiteflies and two-spotted mites on greenhouse cucumbers can be controlled by parasites and predators in conjunction with chemical insecticides. The harmonious use of biological agents and chemicals to control pests is known as integrated control. Chemicals and application methods should be selected to present minimal hazard to the biological agents. Heavily pest infested areas may require spot treatment, but overall sprays should be avoided. Chemicals applied to control pests other than mites and whiteflies should be selected to be compatible with the biological agents. Chemicals used to decrease pest numbers before introducing biological agents should have little or no residual action.

EFFECT OF GREENHOUSE PESTICIDES ON THE MITE PREDATOR & WHITEFLY PARASITE (Encarsia)

Pesticide	Application Method	Effect on Predator Mites	Effect on Whitefly Parasites	Known residual action
Ambush	spray	harmful	harmful	long
Benomyl	spray	negligible	negligible	
Botran	spray	negligible	negligible	
Bravo	spray	negligible	negligible	
Captan	spray	negligible	negligible	
Diazinon	soil drench	negligible	negligible	
Dibrom	fumigant	harmful	harmful	short
Insecticidal soap	spray	harmful	harmful to adults	short
Kelthane	spray	harmful	negligible	
Mancozeb	spray	negligible	unknown	
Maneb	spray	negligible	slight	
Parathion	fumigant	harmful	harmful	short
Plictran*	spray	negligible	negligible	
Sevin	spray	harmful	harmful	long
Tedion	fumigant	negligible	negligible	
Thiodan	spray	negligible	harmful	moderate
Vendex	spary	negligible	unknown	

* *not registered for greenhouse food crops*

Biological agents should be introduced at the first sign of mites or whiteflies. INTRODUCTIONS INTO HEAVY INFESTATIONS HAVE NO CHANCE FOR SUCCESSFUL CONTROL.

WHITEFLY CONTROL

A parasitic wasp, *Encarsia formosa*, is used to control whiteflies in greenhouses. Start early in the season and examine plants regularly. When the first adult whiteflies are seen, obtain and release parasites.

Place a piece of cardboard bearing black parasite scales at intervals along the rows. Use at least 5 parasites per plant. It is advisable to introduce parasites four times at 10-14 day intervals. When the lower leaves bearing parasitized scales must be trimmed off they should be kept in the greenhouse until the adult parasites have emerged. Do not use Ambush one month prior to introduction of *Encarsia*.

MITE CONTROL

Phytoseiulus persimilis, a predatory mite, is effective in controlling two-spotted spider mites in greenhouse cucumbers. Examine plants regularly for early signs of mite feeding. As soon as the first sign of feeding appears, introduce predators onto the cucumber plant or leaf material at the rate of one predator per plant in the entire greenhouse. Do not trim predator infested leaves off the plant. Continue to examine the planting regularly for spot outbreaks of 2-spotted mites and make further introductions of predators if necessary.

Further information can be obtained from the greenhouse crops specialist at the Alberta Horticultural Research Center, Bag Service 200, Brooks, Alberta TOJ OJO Growers in Alberta may purchase biological control agents from: Applied Bionomics Ltd., Research Station, Sydney, BC, phone: (604) 656-2123.

APHIDS

Mainly a pest of cucumber, aphids are soft-bodied, sucking insects, yellowish-green to black in color, clustered on growing tips of plants or on the underside of lower leaves. They cause wilting and yellowing of leaves. Aphids excrete honeydew, an ideal medium for the growth of fungi. They can also carry and transmit virus diseases.

Control: Thiodan 4E, 125 mL/100 L of spray (do not apply within 2 days of harvest). Thorough coverage of the undersides of a leaf is essential for whitefly control. OR 10% Parathion smoke (do not apply within 1 day of harvest). Parathion vapors are extremely poisonous. Use a respirator with proper cartridge and ventilate thoroughly before resuming work in the greenhouse. (NOTE: This can be very damaging to seedling cucumbers.) OR insecticidal soap, 2.5 L/100 L can be applied up to harvest. Insecticidal soap acts only by direct contact so thorough coverage is essential. Phytotoxicity can occur if label rate is exceeded.

WHITEFLY (TRIALEUROIDES)

These tiny, white moth-like insects lay eggs on the underside of leaves and the pale-green scale-like larvae emerge in 11-14 days. They feed by sucking sap from leaves. The adult stage is reached in 4 weeks. They breed throughout the year with the length of life cycle dependent on temperature.

Control: Same as for aphids. OR use parasites (see Integrated Control section). OR Ambush 50 EC at 20 mL/100 L (do not apply within 1 day of harvest). OR Insecticidal Soap, 1 L/100 L, can be applied up to harvest. This reduced rate may be integrated with a parasite program as it is slightly more toxic to whiteflies than to Encarsia. The above materials mainly control adults. Repeat applications at 5-day intervals to prevent egg-laying by newly emerged adults.

CLIMBING CUTWORMS AND CATERPILLARS

These are dark-colored fleshly worms up to 4 cm long which feed at night and are seen during the day in soil. They feed at or below ground level, or may climb and feed on aerial portions of the plant. Freshly transplanted succulent plants are especially susceptible. Caterpillars can be found on above ground parts during the day as well as at night; they are not nocturnal as are cutworms.

Control: Screen air inlets with 5 mm mesh to keep out adult moths OR Sevin 50 WP, 200 g/100 L (do not apply within 1 day of harvest). Apply to solid and lower parts of plants. OR Ambush 50 EC at 20 mL/100 L. OR Parathion smoke fumigators (follow label directions). Do not apply within 1 day of harvest.

MILLIPEDES

These many-legged worms live within soil and humus piles, where they feed mainly on dead plant material. They can attack living tissue of roots and stems.

Control: Malathion 4% dust, 2.5 kg/100 m^2 before planting.

STRAW MITES (TYROGLYPHUS)

This creamy white mite is introduced to greenhouses on manure or straw. It begins feeding on and within the unfolding leaves of the shoot tips soon after plants have been set out. First signs are small perforations of the young leaves. As the leaves grow, the perforations expand into irregular holes, the leaves are distorted and blindness of the growing points may occur.

Control: Parathion smoke fumigators (follow label directions). Do not apply within 1 day of harvest.

TWO-SPOTTED MITES (TETRANYCHUS)

These tiny spider-like creatures feed on plant juices causing leaves to turn yellow and die.

Control: Use predators (see Integrated Control) OR Kelthane 18.5 EC at 125 mL/100 L (do not apply within three days of harvest) OR Vendex 50W at 50 g/100 L. Do not apply to cucumbers within 3 days of harvest. OR Tedion smoke generators at label rates (do not apply within 1 day of harvest).

THRIPS

Adult thrips are tiny insects 0.75 mm long with feathery wings. They develop on weeds and invade the greenhouse, through cracks or vents. Inside the greenhouse, they feed on the undersides of leaves, growing tips and flowers. This feeding results in small, bleached dead spots on the leaf surface, damaged growing tips and flowers. Eggs are laid in leaf tissue. The newly hatched thrips look like tiny yellow worms.

After feeding on the underside of the leaves for 2 weeks, they drop to the soil where they burrow in and pupate. In approximately 1 week, they emerge to repeat the cycle. The total time from egg to adult is 1 month.

Control: A 3-3.5 m wide strip of bare ground around the greenhouse delays or even prevents thrips invasion. The herbicide Roundup is effective for initial clean-up of weeds while Gramoxone will control weed regrowth.

Parathion will give good control of thrips but it is deadly on predator mites and whitefly parasites so it must not be used in a program using biological agents. Thrips can be controlled by spraying diazinon 50EC at the rate of 100 mL 100 L to treat 200 m^2 on the soil, NOT ON THE PLANTS. This will kill the immature thrips that drop from the leaves to the ground to pupate, as well as the adults that emerge from the soil. Two sprays should be applied: the first as soon as thrip damage is noticed and the second two weeks later. Repeat if the greenhouse is reinvaded by thrips as indicated by dead spots on the leaves.

In greenhouses where biological control of whiteflies or mites is not being carried out use: Thiodan 4E at 125 mL/100 L. Thiodan may be used as spot treatments of infestations in greenhouses where predators or parasites have been introduced. OR 10% Parathion smoke (do not apply within 1 day of harvest). Parathion vapors are extremely poisonous. Use respirator with proper cartridge and ventilate thoroughly before resuming work in the greenhouse.

SOWBUGS

(Also pill bugs or woodlice). These small many-legged pests live in the soilbed during day and feed on roots and stems at night. The body is segmented, about 12 mm long and 6 mm wide.

Control: Malathion 4% dust, 2.5 kg/100 m^2 before planting. If not controlled, sowbugs can damage young plants.

SLUGS

Black or grey slugs are 6-12 mm long and feed on cucumber stems and roots.

Control: Use Metaldehyde spray or bait according to manufacturer's directions. For ease of application, use spray on small plants and bait around larger plants.

FUNGUS GNATS

The larvae of these small dark grey or black flies are pests of greenhouse plants. Larvae are slender and white with black heads. In cucumber plants they can attack the tap roots and stem cortex near the soil level and can feed on the root hairs. Affected plants usually grow slowly although some may actually collapse.

Control: Diazinon — 50 WP at 50 g/100 L. Apply as a drench using sufficient volume to wet growing medium.

SPRINGTAILS

Springtails are becoming more of a pest to crops in sawdust culture than had previously been recognized. Long English cucumbers appear to be damaged more readily than tomatoes.

Springtails are the most common insect found in soils.

They vary in coloration from white to metallic grey. They commonly range in size from 0.3 to 2 mm. Springtails feed on fungi, bacteria, decaying plant material, pollen and algae, but only a few species feed on living plant material. Most springtails are capable of leaping and this is often an aid to identification. All stages are wingless.

Have suspected insects identified before deciding on a control program. It is important to differentiate between symphilids, nonjumping springtails and jumping springtails as control methods vary. Regular inspection of your sawdust bags will help determine if springtail populations warrant control.

Cucumber plants suffering from springtail damage look healthy but are slow growing, often fail to set fruit and may wilt in sunny weather. For information on control measures, contact the greenhouse specialist at the Alberta Horticultural Research Center, Brooks, Alberta.

MICE

Use a combination of preventative measures to control mice, including baiting with poisons and trapping.

1. Preventative Control Methods

   Mice avoid areas that do not provide cover. Destroy vegetation with herbicides or by cultivation. Remove tall weeds and grasses, brush piles and other trash from around buildings and other places where mice congregate. This helps keep mice out of the area and prevents numbers from increasing.

2. Poison Baits

   Poison baits should be placed in bait stations to protect them from the weather and to prevent accidental poisoning of other animals. The disappearance of the contents will indicate that mice are still present. Stations can be easily constructed from old fluming, cans and pieces of wood or can be purchased commercially. They should be placed at 3-4 m intervals in the areas where mice are numerous such as trash piles and buildings. Place bait stations around the perimeter of an area to prevent mice from entering. Weather-proof baits should be used outdoors.

   Use zinc phosphide — single dose. OR calciferol — 2-4 days of feeding required. OR brodifacoum — only single feeding necessary, time of death up to 2 weeks. OR bromadiolone — only single feeding necessary, time of death up to 2 weeks. WARNING: Poison baits are highly toxic to animals.

3. Trapping

   Traps may be preferred in some instances. Proper placement and use of an attractive bait such as peanut butter is necessary to ensure effective control.

   Traps available are: a) snap or spring trap; b) live trap — single or multiple catch.

PESTICIDE SAFETY

KNOW YOUR PESTICIDES

Read the label — read it all, even the small print.

Know the relative toxicity and hazards of the pesticide.

Use pesticides only when they are actually needed. Use only the pesticide that is recommended for the problem.

PROTECTIVE CLOTHING

Wear coveralls, respirator, boots, gloves and a wide brim hat when using very toxic pesticides. Do not tuck pant cuffs inside your boots. Use waterproof clothing if there is a danger of getting wet from the spray.

For less toxic pesticides, adequate clothing should be worn to prevent skin contact. Wear rubber or neoprene gloves and goggles when mixing any pesticides.

Clean protective clothing after use.

RESPIRATORS

Respirators must be worn when specified on the label. Make certain that your respirator fits and is rated to give protection for the chemical you intend to use.

Respirator cartridges remove toxic chemicals from the air. Dust filters simply remove dust. Both must be replaced regularly for the repirator to be effective. Use manufacturer's directions or maintain your respirator as follows:

1. Change felt dust filters after 4 hours of use or more often if breathing becomes difficult.
2. Change cartridges after 8 hours of use, or sooner if any odor of pesticide is noticed.
3. Wash the facepiece of a respirator with warm soap and water after using, rinse thoroughly with clean water and dry well with a clean cloth.
4. Keep your cleaned respirator in a clean, dry place enclosed in a sealed plastic bag.

INDOOR USE OF FUMIGANTS, SMOKE GENERATORS AND FOGGERS

When applying extremely toxic or very toxic pesticides indoors, a full face gas mask with correct canister should be used. Keep a fresh canister on hand as they lose their effectiveness after a certain time.

For methyl bromide, a self-contained breathing apparatus which supplies clean air is recommended for indoor work. However, a gas mask with a special canister can be used when applying the fumigant if you leave the area immediately.

Wear a full face mask when lighting a smoke generator and when aerating the house. Light the bomb farthest from the door and work toward the door. If smoke bombs are placed in more than one path, more than one person should light them.

When using fogging machines, wear complete protective clothing including hat, jacket, pants or coveralls, rubber gloves, and an airtight, full-face mask.

DISPOSAL OF UNWANTED PESTICIDES

Calculate accurately the amount of pesticide needed so that a minimal amount is left over.

Drain small amounts of leftover spray into a hole in an isolated area and cover the hole with soil. Pesticides must not be dumped near any waterway.

For information on disposal of pesticides products, contact the regional office in the Pesticide Chemical Branch, Pollution Control Division of Alberta Environment, 5th Floor, Oxbridge Place, 9820 - 106 Street, Edmonton, Alberta T5K 2J6.

DISPOSAL OF CONTAINERS

Destroy or dispose of empty triple-rinsed containers immediately; do not leave empty containers scattered around.

Dispose of empty pesticide containers by burial in a sanitary landfill. If there is no public landfill in the area, flatten containers and bury them at least 45 cm deep where there is no danger of water contamination.

Some pesticide labels caution against burning of packages. Fumes may be toxic or damaging to plants. If burning is safe, bury the ashes.

Glass jars should be broken in the burial pit and metal or plastic containers crushed or punched with holes to render them useless.

STORAGE

1. Keep pesticides out of reach of children and pets. Legally all pesticides must be stored in a ventilated, locked shed with a warning sign on the door. Store away from food, feeds, fertilizers and seeds.
2. Store volatile herbicides separately from other pesticides, fertilizers and seeds.
3. Always store pesticides in their original containers. Keep the containers tightly closed and dry. Avoid freezing of liquid formulations.

4. When not in use return pesticides to storage
5. Dispose of: a) pesticides no longer required
   b) containers which are unmarked, corroded or damaged

For disposal instructions see above.

SYMPTOMS OF PESTICIDE POISONING

Read the label for poisoning symptoms. The symptoms of pesticide poisoning vary from person to person and are often difficult to recognize. If any illness or abnormal condition occurs during or after exposure to pesticides, contact a doctor immediately. Provide him with label information.

FIRST AID

Call your doctor or Poison Control Centre immediately if there has been a suspected poisoning.

The label has detailed first aid information.

Give the information to the doctor.

For your convenience, space has been made available on the front cover of your telephone directory for the telephone numbers of your Poison Control Centre and doctor.

WARNING
Do not induce vomiting if a corrosive (acid or alkali) or petroleum product is accidentally swallowed

POISON CONTROL CENTRES

All hospitals in Alberta are poison control centres. They provide first aid information and treatment of poisoning for toxic chemicals.

Know the telephone number of your nearest hospital.

AFTER APPLYING PESTICIDES

Clean the equipment thoroughly.

Clean and store your clothing and protective equipment.

Wash yourself thoroughly.

Observe the required waiting period before harvest.

REENTRY TO TREATED AREAS

It is your responsibility to warn your farm workers of areas recently treated with pesticides.

Pesticide poisoning may occur where workers enter treated areas too soon after pesticides have been applied. Such poisoning may result from inhalation to pesticide vapors but more often from handling treated plants.

For some pesticides e.g. [illegible] the label carries a warning regarding working in treated crops. Follow these directions. Where no label warnings are provided, it is advisable to wait at least 24 hours following spray application of any material rated as very toxic (dermal or oral) as listed in the 'Relative Toxicity of Pesticides' table in this publication, before reentry.

Longer periods are advised where wettable powder formulations of these materials have been used and when there will be substantial contact with the sprayed foliage. Although there is a lack of specific information on how long this period should be, a minimum of 48 hours is suggested.

RECORDS

Keep good records of all pesticide use.

THE DANGER OF APPLYING PESTICIDES AND FERTILIZER THROUGH THE IRRIGATION SYSTEM

Pesticide application through the irrigation system is not recommended because such an application presents a real danger to the water supply.

THE DANGER OF FILLING THE SPRAYER TANK FROM STAND PIPES, FROM DOMESTIC WATER TAPS, LAKES OR STREAMS

If the end of the filler hose is submerged in the spray liquid during filling, there is a danger of contaminating the water supply by backflow. A 15 cm AIR GAP must be maintained between the end of the filler hose and the liquid in the tank. Use an antifoaming agent or 15 mL of cooking oil to prevent foaming.

If filling spray tanks from a lake or stream, equipment must have an anti-siphon check valve.

RELATIVE TOXICITY OF PESTICIDES

The toxicity data are based on tests with rats and rabbits and are considered relevant to all mammals including humans. The principal source of information for the table is Acute Toxicity Data for Pesticides (1970), R. BenDyke, D.M. Sanderson and Diana N. Noakes. The following categories have been used: Dermal — LD50, 0-200, very toxic; 200-1,000 toxic; 1,000 up, slightly toxic. Oral — LD50, 0-50, very toxic; 50-500, toxic, 500 up, slightly toxic.

Very Toxic

ORAL (by mouth)	DERMAL (skin absorption)
chloropicrin	chloropicrin
Cyanogas	Cyanogas
Gramoxone (paraquat)	methyl bromide
methyl bromide	parathion

Mouse Bait 2
(zinc phosphide)
parathion
Ramik Brown
(diphacinone)
Thiodan (endosulfan)
zinc phosphide
calciferol
brodifacoum
bromadiolone

Although the toxicity rating of Gramoxone (paraquat) has not been clearly established as "very toxic" there is no doubt that swallowing it could be fatal. There is no specific antidote for Gramoxone (paraquat). Use extreme precaution to avoid accidental swallowing of this herbicide.

Toxic

ORAL (by mouth)	DERMAL (skin absorption)
diazinon	formaldehyde
Dibrom (naled)	Thiodan (endosulfan)
fixed copper	
formaldehyde	
Plictran (cyhexatin)	
Sevin (carbaryl)	

Slightly Toxic

ORAL (by mouth)	DERMAL (skin absorption)
Ambush (permethrin)	Ambush (permethrin)
Benlate (benomyl)	Benlate (benomyl)
Botran (dichloran)	Bravo (chlorothanlonil)
Bravo (chlorothalonil)	captan
captan	Daconil (chlorothalonil)
Daconil (chlorothalonil)	diazinon
Dyrene (anilazine)	Dibrom (naled)
Exotherm Termil Ethrel (ethephon) (chlorothalonil)	Exotherm Termil (chlorothalonil)
Kelthane (dicofol)	fixed copper
mancozeb	Kelthane (dicofol)
maneb	mancozeb
metaldehyde	maneb
Tedion (tetradifon)	metaldehyde
Termil (chlorothalonil)	Plictran (cyhexatin)
thiram	Roundup (glyphosate)
Vapam (metam)	Sevin (carbaryl)
Vendex	Tedion (tetradifon)
Roundup (glyphosate)	Termil (chlorothalonil)
	thiram
	Vapam (metam)
	Vendex (fenbutatin oxide)

PESTICIDE COMMON AND TRADE NAMES

Trade names are capitalized. Common names are not capitalized.

Fungicides

Arasan .... thiram
Benlate .... benomyl
Benomyl .... Benlate
Botran .... dechloran
Bravo .... chlorothalonil
captan .... Captan, Orthocide
chlorothalonil .... Daconil, Exotherm Termil
Copper oxychloride .... fixed copper
Daconil .... chlorothalonil
Exotherm Termil .... chlorothalonil
fixed copper .... Neutro-Cop, Tri-Cop
Orthocide .... captan
Termil .... chlorothalonil
thiram .... Thiram, Arasan, Thylate
Thylate .... thiram
Tri-Cop .... fixed copper

Insecticides

Basudin .... diazinon
carbaryl .... Sevin
diazinon .... Basudin
Dibrom .... naled
naled .... Dibrom
parathion .... Parathion
Sevin .... carbaryl
Ambush .... permethrin

Fumigants

chloropicrin .... Chloropicrin
Cyanogas .... Cyanogas
Dowfume MC-2 .... methyl bromide
formaldehyde .... formalin
formalin .... formaldehyde
metam .... Vapam
methyl bromide .... Dowfum MC-2
Vapam .... metam

Molluscicide

metaldehyde .... Slug Bait
Slug Bait .... metaldehyde

Miticides

dicofol .... Kelthane
Kelthane .... dicofol
Tedion .... tetradifon
tetradifon .... Tedion
vendex .... fenbutatin oxide

Herbicides

glyphosate .... Roundup
Gramoxone .... paraquat
paraquat .... Gramoxone
Roundup .... glyphosate

Rodenticides

bradifacoum .... Ratak, Talon
bromadiolone .... Bromone, Maki
Bromone .... bromadiolone
calciferol .... Sorexa
Maki .... bromadiolone
Mouse Bait 2 .... zinc phosphide
Ratak .... brodifacoum
Sorexa .... calciferol
Talon .... brodifacoum
zinc phosphide .... Mouse Bait 2

GOING METRIC

SYMBOLS

LENGTH

mm	millimetre
cm	centimetre
m	metre
km	kilometre

WEIGHT

g	gram
kg	kilogram
t	tonne

PRESSURE

kPa	kilopascal

VOLUME

mL	millilitre
L	litre
hL	hectolitre
m^3	cubic metre

AREA

cm^2	square centimetre
m^2	square metre
ha	hectare
km^2	square kilometre

TEMPERATURE

°C	degrees Celsius

PREFIXES

mega	million	1 000 000
kilo	thousand	1 000
hecto	hundred	100
deca	ten	10

deci	tenth	0.1
centi	hundredth	0.01
milli	thousandth	0.001
micro	millionth	0.000 001

MEASURES

LENGTH

10 mm	1 cm
100 cm	1 m
1 000 m	1 km

WEIGHT

1 000 g	1 kg
1 000 kg	1 t

VOLUME

1 000 mL	1 L
100 L	1 hL
1 000 L	1 m^3

AREA

10 000 cm^2	1 m^2 (100 cm x 100 cm)
10 000 m^2	1 ha (100 m x 100 m)
100 ha	1 km^2 (1000 m x 1000 m)

INTER-RELATION

Water at 4°C	Length	Volume	Weight
1,000 cm^3	1,000 cc	1 L	1 kg
1 cm^3	1 cc	1 mL	1 g

METRIC CONVERSION TABLES

Double conversion tables for weights and measures:

The middle column represents either of the two columns beside them, as the case may be.

Example 1:

1 cm	0.394 inches
1 inch	2.540 cm

Example II:

123 km	62.136
	12.427
	1.864
	miles 76.427
123 miles	160.936
	32.187
	4.828
	km 197.951

Length

Centimetres ←		→ Inches	Metres ←		→ Yards	Kilometres ←		→ Miles
2.540	1	0.394	0.914	1	1 094	1.609	1	0.621
5.080	2	0.787	1.829	2	2.187	3.219	2	1.243
7.620	3	1 181	2.743	3	3.281	4.828	3	1.864
10.160	4	1.575	3.658	4	4.374	6.437	4	2.485
12.700	5	1.969	4.572	5	5.468	8.047	5	3.107
15.240	6	2.362	5.486	6	6.562	9.656	6	3.728
17.780	7	2.756	6.401	7	7.655	11.266	7	4.350
20.320	8	3.150	7.315	8	8.749	12.875	8	4.971
22.860	9	3.543	8.320	9	9.843	14.484	9	5.592
25.400	10	3.937	9.144	10	10.936	16.094	10	6.214
50.800	20	7.874	18.288	20	21.872	32.187	20	12.427
76.200	30	11.811	27.432	30	32.808	48.281	30	18.641
101.600	40	15.748	36.576	40	43.745	64.375	40	24.855
127.000	50	19.685	45.720	50	54.681	80.468	50	31.068
152.400	60	23.622	54.863	60	65.617	96.562	60	37.282
177.800	70	27.559	64.007	70	76.553	112.655	70	43.495
203.200	80	31.496	73.151	80	87.489	128.750	80	49.709
228.600	90	35.433	82.295	90	98.425	144.843	90	55.923
254.000	100	39.370	91.439	100	109.361	160.936	100	62.136

Area

Square Metres ←		→ Square Feet
0 093	1	10 76
0 186	2	21 53
0 279	3	32 29
0.372	4	43 06
0 465	5	53 82
0 557	6	64 58
0 650	7	73 35
0 743	8	86 11
0 836	9	96 88
0 929	10	107 64
1 858	20	215 28
2 787	30	322 92
3.716	40	430 56
4.645	50	538.19
5.574	60	645 83
6.503	70	753 47
7.432	80	861.11
8.361	90	668 75
9 290	100	1,076.39

Square Metres ←		→ Square Yards
0 836	1	1 196
1 672	2	2 392
2 508	3	3 588
3 345	4	4 784
4 181	5	5 980
5 017	6	7 176
5 843	7	8 372
6 689	8	9 568
7 525	9	10 764
3 361	10	11 960
16 723	20	23 920
25 084	30	35 880
33 445	40	47 840
41 806	50	59 800
50 168	60	71 759
58 529	70	83 719
66 890	80	95 679
75 251	90	107 639
83 613	100	119 599

Hectares ←		→ Acres
0 405	1	2 471
0 809	2	4 942
1 214	3	7 413
1 619	4	9 884
2 023	5	12 355
2 428	6	14 826
2 833	7	17 297
3 238	8	19 768
3 642	9	22 239
4 047	10	24 711
8 094	20	49 421
12 141	30	74 132
16 187	40	98 842
20 234	50	123 553
24 281	60	148 263
28 328	70	172 974
32 275	80	197 684
36 422	90	222 395
40 469	100	247 105

Litres per Hectare ←		→ Gallons Per Acre
11 233	1	0 08902
22 466	2	0 17804
33 699	3	0 26706
44 933	4	0 35608
56 166	5	0 44510
67 399	6	0 53412
78 632	7	0 62315
89 865	8	0 71217
101 098	9	0 80119
112 332	10	0 89021
224 663	20	1 78042
336 995	30	2 67062
449 326	40	3 56083
561 658	50	4 45104
673 989	60	5 34125
786 321	70	6 23146
898 652	80	7 12166
1,010 984	90	8 01187
1,123 315	100	8 90208

Volume

Litres ←		→ Gallons
4.546	1	0.220
9.092	2	0 440
13.638	3	0.660
18.184	4	0 880
22.730	5	1.100
27.276	6	1.320
31.822	7	1 540
36 368	8	1.760
40 914	9	1 980
45.460	10	2 200
90.919	20	4 399
136 379	30	6 599
181.838	40	8.799
227.298	50	10 99
272.758	60	13.198
318.217	70	15.398
363.677	80	17.598
409 136	90	19 797
454.596	100	21 997

Litres ←		→ Gallons (U S.)
3 785	1	0 264
7 571	2	0 528
11.356	3	0 793
15.141	4	1 057
18 927	5	1.321
22 712	6	1 585
26 497	7	1 849
30 282	8	2 113
34 068	9	2 378
37.853	10	2 642
75.706	20	5 284
113.559	30	7.925
151 412	40	10 567
189 265	50	13 209
227.118	60	15.851
264.971	70	18 493
302.825	80	21 134
340 678	90	23 776
387 531	100	26 418

Millilitres per 100 Litres ←		→ Pints per 100 Gallons
125	1	0 008
250	2	0 016
375	3	0 024
500	4	0 032
625	5	0 040
750	6	0 048
875	7	0 056
1,000	8	0 064
1,125	9	0 072
1,250	10	0 080
2,500	20	0 160
3,750	30	0 240
5,000	40	0 320
6,250	50	0 400
7,500	60	0 480
8 750	70	0 560
10,000	80	0 640
11,250	90	0 720
12 500	100	0 800

Millilitres per 100 Litres ←		→ Fluid Ounces 100 Gallons
6 24	1	0 16
12 47	2	0 32
18 71	3	0 48
24 94	4	0 64
31 18	5	0 80
37 41	6	0 96
43 65	7	1 12
49 89	8	1 28
56 13	9	1 44
62 36	10	1 60
124 72	20	3 21
187 09	30	4 81
249 45	40	6 41
311 81	50	8 02
374 17	60	9 62
436 53	70	11 22
498 90	80	12 83
561 26	90	14 43
623 62	100	16 04

Weight

Kilograms ←		→ Pounds
0.454	1	2 205
0.907	2	4.409
1.361	3	6.614
1.814	4	8 818
2.268	5	11.023
2.722	6	12 228
3.175	7	15 432
3.629	8	17 637
4.082	9	19 842
4.536	10	22 046
9.072	20	44 092
13.608	30	66.139
18.144	40	88.185
22.680	50	110.231
27.215	60	132.277
31.751	70	154.323
36.287	80	176.370
40.823	90	198.416
45.359	100	220.462

Grams ←		→ Ounces (Dry)
28.350	1	0 035
56.699	2	0 071
85 049	3	0 106
113.398	4	0 141
141.748	5	0 176
170.097	6	0 212
198 447	7	0 247
226.796	8	0 282
225.146	9	0 318
283.495	10	0 353
566.990	20	0 706
850.485	30	1 058
1,133.980	40	1 411
1,417.475	50	1 764
1,700 970	60	2.116
1,984.465	70	2 469
2,267.960	80	2 822
2,551.455	90	3.175
2,834.950	100	3 527

Kilograms Per Hectare ←		→ Pounds per Acre
1 121	1	0 892
2 242	2	1 784
3 363	3	2 677
4 483	4	3 569
5 604	5	4 461
6 725	6	5 353
7 846	7	6 245
8 967	8	7 137
10 088	9	8 030
11 209	10	8 922
22 417	20	17 844
33 626	30	26 765
44 834	40	35 687
56 043	50	44 609
67 251	60	53 531
78 460	70	62 453
89 668	80	71 374
100 877	90	80 296
112 085	100	89 218

Grams per 100 Litres ←		→ Ounces per 100 Gallons
6 24	1	0 16
12 47	2	0 32
18 71	3	0 48
24 94	4	0 64
31 18	5	0 80
37 41	6	0 96
43 65	7	1 12
49 89	8	1 28
56 13	9	1 44
62 36	10	1 60
124 72	20	3 21
187 09	30	4 81
249 45	40	6 41
311 81	50	8 02
374 17	60	9 62
436 53	70	11 22
498 90	80	12 83
561 26	90	14 43
623 62	100	16 04

Temperature

Celsius ←		→ Fahrenheit
—40.0	—40	—40.00
—34.4	—30	—22.0
—28.9	—20	—4.0
—23.3	—10	+ 14.0
—17.8	0	+ 32.0
—17.2	1	+ 33.8
—16.7	2	+ 35.6
—16.1	3	+ 37.4
—15.6	4	+ 39.2
—15.0	5	+ 41.0
—14.4	6	+ 42.8
—13.9	7	+ 44.6
—13.3	8	+ 46.4
—12.8	9	+ 48.2
—12.2	10	+ 50.0
—6.7	20	+ 68.0
—1.1	30	+ 86.0
+ 4.4	40	+ 104.0
+ 10.0	50	+ 122.0
+ 15.6	60	+ 140.0
+ 21.1	70	+ 158.0
+ 26.7	80	+ 176.0
+ 32.2	90	+ 194.0
+ 37.8	100	+ 212.0

Volume (Rounded-off)

Gallons ←	→ Litres
25	110
50	230
95	430
100	450
195	890
200	910
260	1,180
300	1,360
400	1,820
500	2,270

U.S. Gallons	Litre
25	90
50	190
55	210
100	380
110	420
125	470
150	570
200	760
300	1,140
400	1,510
500	1,890

CONVERSION FACTORS

Imperial Units	Conversion Factor	Metric Units
LENGTH		
inches	2.5	centimetres
feet	30	centimetres
feet	0.3	metres
yards	0.9	metres
miles	1.6	kilometres
AREA		
square inches	6.5	square centimetres
square feet	0.09	square metres
acres	0.40	hectares
VOLUME		
cubic inches	16	cubic centimetres
cubic feet	0.03	cubic metres
cubic yards	0.8	cubic metres
fluid ounces	28	millilitres
pints	0.57	litres
quarts	1.1	litres
gallons (Imperial)	4.5	litres
gallons (U.S.)	3.75	litres
bushels	0.36	hectolitres
WEIGHT		
ounces	28	grams
pounds	0.45	kilograms
short tons (2,000 lb.)	0.9	tonnes
TEMPERATURE		
degrees Fahrenheit (F-32)	0.56	degrees Celsius
POWER		
horsepower	750	watts
	0.75	kilowatts

Imperial Units	Conversion Factor	Metric Units
oz./acre	70	g/ha
lb./acre	1.12	kg/ha
bu./acre	0.9	hL/ha
tons/acre	2.24	t/ha
fl.oz./acre	70	mL/ha
pt./acre	1.4	L/ha
qt./acre	2.8	L/ha
gal./acre	11.2	L/ha
gal./acre(U.S.)	9.35	L/ha
plants/acre	2.47	plants/ha
oz./gal	6.2	mL/L
lb./gal.	0.1	kg/L
oz./sq.ft.	305	g/m^2
lb./sq.ft.	4.9	kg/m^2
oz./ft.row	93	g/m row
lb./ft. row	1.5	kg/m row
ft./sec.	0.3	m/s
m.p.h.	1.6	km/h
p.s.i.	6.9	kPa
PRESSURE		
psi (lb/in^2)	6.89	kilopascals (kPa)
inches of water	0.25	kilopascals (kPa)
ENERGY		
British thermal unit (Btu)	1.06	kilojoules (kJ)
Btu/hr	0.293	watts (W)
Btu/hr/sq. ft.	3.15	watts per square metre (W/m^2)
kilowatt hours	3.60	megajoules (MJ)

USEFUL MEASUREMENTS

1 Imperial gallon = 4 quarts = 8 pints = 160 fluid ounces
= 10 pounds of water
= approximately 1.2 U.S. gallons
1 U.S. gallon = .8345 or approximately 5/6 Imperial gallon
1 Imperial pint = 20 fluid ounces
1 U.S. pint = 16 fluid ounces
1 pound = 16 ounces
1 tablespoon = 3 teaspoons
2 tablespoons = 1 fluid ounce

1 pound in 100,000 gallons of water = 1 ppm (part per million)
1 mile = 5,280 feet = 1,760 yards
1 yard = 3 feet = 36 inches
1 foot = 12 inches
1 acre = approximately 209 by 209 feet
43,560 square feet
1 square yard = 9 square feet
1 square foot = 144 square inches
1 mile an hour = 88 feet a minute

PARTS PER MILLION

1 per cent = 10,000 parts per million
Imperial: 1 fl. oz./gallon = 6250 ppm.

Metric: 1 mg/litre (water) = 1 ppm
1 g/litre (water) = 1000 ppm
1 mL/litre = 1000 ppm

SOLUBILITY OF FERTILIZERS IN COLD AND HOT WATER

Fertilizer	Solubility g per 100 ml Water Cold	Hot
Ammonium nitrate	118.3 (0)	871.0 (100)
Ammonium sulphate	70.6 (0)	103.8 (100)
Calcium nitrate	102.5 (0)	376.0 (100)
Urea	78.0	
Monoammonium phosphate	22.7 (0)	173.2 (100)
Diammonium phosphate	57.5 (0)	106.0 (70)
Potassium carbonate	112.0 (20)	156.0 (100)
Potassium chloride	34.7 (20)	56.7 (100)
Potassium nitrate	13.3 (0)	247.0 (100)
Potassium sulphate	12.0 (25)	24.0 (100)
Potassium orthophosphate	90.0	(20)
Monopatassium phosphate	167.0	(20)
Magnesium sulphate	26.0 (0)	73.8 (100)
Sodium borate (Borax)	1.6 (10)	14.2 (55)
Solubor	4.5 (10)	32.0 (50)
Copper sulphate	31.6 (0)	203.3 (100)
Manganese sulphate	105.3 (0)	111.2 (54)
Ferrous sulphate	15.6	48.6 (50)
Sodium molybdate	56.2 (0)	115.5 (100)

The figures in parentheses are the temperatures (°C) at which the solubilities were determined.

$$PPM = \frac{\text{grams of fertilizer product}}{\text{litres of water in solution}} \times \text{grade of fertilizer} \times 10$$

KNOWN PESTICIDE COMPATIBILITY

\+ Compatible
— Not Compatible
1 Use WP only
2 Apply immediately with Tank Agitation
3 Use with caution (possible plant injury)
□ Not used together or compatibility unknown.

	AMBUSH	BENLATE	BOTRAN	BRAVO	CAPTAN	DYRENE	DIAZINON	DIBROM	FIXED COPPER	KELTHANE	LINDANE	LANNATE	MALATHION	MANEB. MANCOZEB	MORESTAN	PARATHION	PIRIMOR	ROVRAL	SAFER'S INSECTICIDAL SOAP	SEVIN	TEDION	THIODAN	VENDEX
BENLATE	+																						
BOTRAN	□	□																					
BRAVO	+	+	+																				
CAPTAN	+	+	+	+																			
DYRENE	□	+	1	+	□																		
DIAZINON	□	+	+	1	+	□																	
DIBROM	□	+	1	+	1	+	+																
FIXED COPPER	□	—	—	+	2	+	2	+															
KELTHANE	□	+	1	□	1	+	+	+	+														
LINDANE	□	+	1	+	1	+	+	+	+	2													
LANNATE	□	+	□	3	+	3	+	+	+	+	+												
MALATHION	□	+	1	1	1	+	+	+	+	+	□	+											
MANEB. MANCOZEB	+	+	1	+	+	+	2	+	2	+	1	+	2										
MORESTAN	□	+	+	+	+	+	+	+	□	□	+	+	+	+									
PARATHION	□	+	1	1	1	+	+	+	+	+	□	+	+	+	+								
PIRIMOR	1	+	□	3	+	□	+	□	□	□	+	+	□	+	□	□							
ROVRAL	+	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	+						
SAFER'S INSECTICIDAL SOAP	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□					
SEVIN	□	+	1	+	+	+	+	+	—	+	+	+	+	+	+	+	+	□	□				
TEDION	□	+	□	□	+	□	+	+	+	1	□	□	+	+	□	+	□	□	□	+			
THIODAN	□	1	+	+	+	+	+	+	1	+	□	+	+	+	+	+	+	□	□	+	+		
VENDEX	□	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	□	+	+	+	
ZINEB	□	+	1	+	□	+	+	+	□	+	1	+	+	□	+	+	□	□	□	+	+	+	+

VEGETABLE RESEARCH AND EXTENSION STAFF
ALBERTA DEPARTMENT OF AGRICULTURE

Specialized Area	Name	Position Description	Address
Greenhouse Production		Greenhouse Specialist	Alberta Horticultural Research Center, Bag 200, Brooks, Alberta TOJ OJO 362-3391
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General Vegetable Production	Paul Ragan	Research Horticulturist Vegetable Crops	Alberta Horticultural Research Center, Bag 200, Brooks, Alberta TOJ OJO 362-3391
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	P.D. Kharbanda	Plant Pathologist	Alberta Environmental Centre, Bag 4000, Vegreville, Alberta TOB 4LO 632-6767
	David Sippell	Plant Pathologist	Regional Crops Laboratory, Box 7777, Fairview, Alberta TOH 1LO 835-2291
Insect Control	Ulf Soehngen	Entomologist	Alberta Horticultural Research Center, Bag 200, Brooks, Alberta TOJ OJO 362-3391
	M. Dolinski	Entomologist	Agriculture Building 7000 - 113 Street, Edmonton, Alberta 427-5339
	Rick Butts	Entomologist	Regional Crops Laboratory, Box 7777, Fairview, Alberta TOH 1LO 835-2291

	Jim Letal	Plant Pathologist	Regional Crops Laboratory Provincial Building, Olds, Alberta TOM 1PO 226-8421
	M. Steiner	Entomologist	Alberta Environmental Centre, Bag 4000, Vegreville, Alberta TOB 4LO 632-6767
	H. Philip	Entomologist	Alberta Environmental Centre, Bag 4000, Vegreville, Alberta TOB 4LO 632-6767
Weed Control	Rudy Esau	Weed Control Specialist	Alberta Horticultural Research Center, Bag 200, Brooks, Alberta TOJ OJO 362-3391
Soil Fertility	R.C. McKenzie	Soil & Water Specialist	Alberta Horticultural Research Center, Bag 200, Brooks, Alberta TOJ OJO 362-3391
	Doug Penney	Soil Fert. Specialist	Agriculture Building 7000 - 113 Street, Edmonton, Alberta 427-5373
Market Gardening	Lloyd Hausher	Market Garden Specialist	Alberta Horticultural Research Center, Bag 200, Brooks, Alberta TOJ OJO 362-3391
	Phil Dixon	Extension Horticulturist	Alberta Tree Nursery and Horticultural Centre R.R. 6, Edmonton, Alberta T5B 4P3 973-3351

GREENHOUSE SOIL ANALYSES LABORATORIES

SOIL

1. Alberta Agriculture
   Soil and Feed Testing
   Laboratory O.S. Longman Building
   6909 - 116 Street
   Edmonton, Alberta T6H 4P2
   (403) 427-6361
   (403) 436-9150

SOIL, TISSUE, WATER

2. Golden West Seeds Ltd.
   915 - 23 Avenue, S.E.
   Calgary, Alberta T2G 1P1
   (403) 263-4200
3. Norwest Soils Research Ltd.
   9938 - 67 Avenue
   Edmonton, Alberta T6E 0P5
   (403) 438-5522

SEED COMPANIES

1. Bruinsma Selectie bedrijven
   Vegetable and Flower Seeds
   822, 7 Street, West
   P.O. Box 1463
   High River, Alberta TOL 1BO
   (403) 652-4768
2. DeRuiter Seeds Inc.
   P.O. Box 20228
   Columbus, Ohio 43220
   United States
   (614) 459-1498
3. Golden West Seeds Ltd.
   915 - 23 Avenue, S.E.
   Calgary, Alberta T2G 1P1
   (403) 263-4200
4. Stokes Seeds Ltd.
   39 James Street
   Box 10
   St. Catharine, Ontario L2R 6R6
   (416) 685-4255
5. Westcan Horticultural Specialists Ltd.
   1900 - 11th Street, S.E.
   Calgary, Alberta T2G 3G2
   (403) 266-5688